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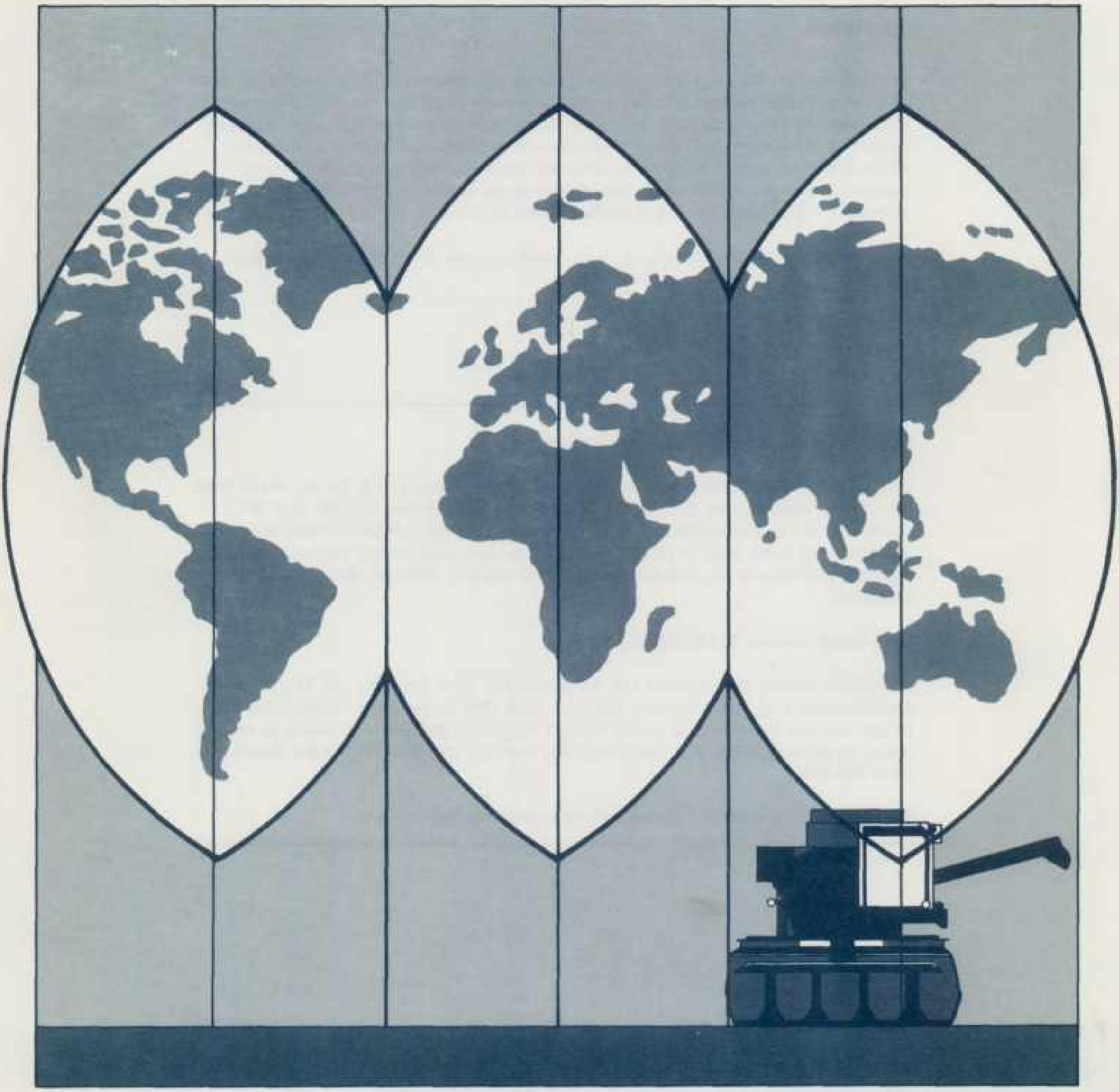
U.S. Agriculture's Potential to Supply World Food Markets

Clark Edwards



U.S. Agriculture's Potential To Supply World Food Markets. By Clark Edwards. National Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 539.

Abstract

Domestic markets are growing too slowly to absorb increases in U.S. farm production. But reliance on foreign markets can make farmers vulnerable to sudden swings in prices, which are transmitted to other domestic sectors as well. This report assesses U.S. agriculture's capacity to meet domestic and export demands, and the likely consequences of doing so, under different economic assumptions about the future. By shifting production among regions, adopting new technology, and keeping up the quality of its resources, U.S. agriculture could double its exports within the next 30 years.

Keywords: capacity, demand, export, farm, future, income, price, production, regions, resources.

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Preface

U.S. agriculture's increasing involvement in world food markets has implications for the size and structure of the farm sector, the level of prices received by farmers, the stability of markets to which farmers sell their products, the level of farm income, and regional variations in agricultural activity. It also has implications for domestic sectors depending on agriculture, such as consumers, postharvest food handlers, and farm input suppliers. Policies adopted by the United States in the late eighties and beyond will affect U.S. agriculture's response to changes in domestic and foreign demand for food during coming decades.

U.S. farm policies introduced in the thirties redistributed income from a relatively well-to-do urban sector to a disadvantaged farm sector, with both sectors comprising a closed economy. That basis for farm policy no longer exists. For one thing, the average U.S. farmer no longer earns less than the average nonfarmer. Furthermore, about 5 percent of the farms now produce half the farm output. This report, however, focuses on reasons that are external to the U.S. economy. U.S. agriculture is now part of an open and volatile world food system that cannot be controlled by domestic policies alone. The need for a farm policy is still with us, but the basis for farm policy has changed.

A study of U.S. agriculture in a world setting was initiated in late 1982 in USDA's Economic Research Service with the idea that there would be one general, broad report covering the potential U.S. food production for world markets and a few special reports that looked at selected topics in depth. Some of the indepth reports were prepared for publication, others were prepared as special materials. Ideas from these reports are reflected in this general report; it could not have been written had the other reports not been available. However, this general report also explores topics not covered in the other reports.

This study was done under the direction of Clark Edwards, Senior Economist, Economic Research Service. Others also prepared papers for publication as part of the world food study, and provided material for this general report:

Robert M. House analyzed the effects of the level of and variability in commodity export demand on U.S. agriculture. He applied and explained the mathematical programming model (USMP) that underlies much of the analysis of the general report (*111*, *112*. See references at end of this report.)

Gerald L. Horner modified the USMP model to analyze irrigation issues. This was a major source of the analytical conclusions in this general report with respect to irrigation (*108*).

Thomas Lutton explained why agriculture may have more flexibility than is generally assumed for making efficient adjustments to alternative world food situations (*150*).

Thomas A. Miller, Jerry A. Sharples, Robert M. House, and Charles V. Moore appraised the supply response of U.S. agriculture to increasing price volatility in world food markets by means of an application of the USMP model (*165, 166*).

Gerald Plato and Douglas Gordon developed a dynamic programming analysis of the probability of meeting alternative objectives of commodity stock management programs using various program strategies (*194*).

Lyle P. Schertz reviewed selected world food studies which took a special look at the role of U.S. agriculture (*217*).

Other contributors prepared special materials as part of the world food study, and contributed to this general report.

Paul Andrilenas and David Torgerson described farm input and productivity, and forecast the availability of purchased farm inputs (*4*).

Robert Boxley discussed the potential for additional cropland, institutional factors affecting the supply of cropland, and considerations of intensity of land use, such as through humid area irrigation and double cropping, which increases production without increasing cropland requirements (*25*).

Barbara Chancey prepared maps describing historical regional variations in farm production, and regional adjustments according to USMP in the U.S. supply response to different levels of exports (*38*).

Michael LeBlanc appraised the likely competition by oil shale development in Colorado, Utah, and Wyoming for resources used by agriculture, particularly water (*135*).

Charles V. Moore analyzed population shifts which are changing the nonfarm demands for natural resources used by farmers. This directly affects the availability of land and water and it indirectly affects the infrastructure available to farmers and the availability of energy. Private markets sometimes fail to allocate such resources in the public interest. The role of public management in these resource markets is discussed (*167*).

Clayton Ogg examined the effect of export market expansion on soil erosion and found that problems vary by commodity and region. For example, expansion of soybean acreage for export in the Delta may result in severe erosion on fragile lands whereas expansion of wheat acreage for export in the Northern Plains need not cause problems (*184*).

Lyle P. Schertz found that projections of economic variables often use models that trace the time path between the present and the future under alternative scenarios. For some models, unrealistically, the economic situation at the endpoint was independent of the time path. In addition, some lead and lag relationships exhibited on the time paths were inconsistent with economic theory (*218*).

Schertz also examined the interaction of agricultural growth in developing countries with general economic development. This has implications for food imports and therefore for growth in the export markets for U.S. farm products. The feedback loop between U.S. food production and production in the rest of the world needs to be evaluated (*219*).

Lloyd D. Teigen described national and regional patterns of input use and productivity and drew implications for agricultural capacity from projections of input use and yields (*238*). Teigen also estimated agricultural output supply and input demand as a simultaneous system (239).

People in ERS who assisted in the study through planning and evaluating sessions, contributing material, and reviewing the manuscripts include: Klaus Alt, Joseph R. Barse, Kenneth C. Clayton, Velmar Davis, J. Larry Deaton, Theodore R. Eichers, Dick Haidacher, Charles Hanrahan, David H. Harrington, Richard Heifner, John Hostetler, Richard Kennedy, John E. Lee, Lester Myers, Patrick M. O'Brien, Anthony C. Prato, Robert Reinsel, Larry E. Salathe, Donald Seaborg, Neill Schaller, Gerald Schluter, James Tannehill, Gary Taylor, Francis Urban, and Alan Webb.

People outside ERS who reviewed this and other manuscripts, listed above, which are part of the overall study, include: James Houck, University of Minnesota; Eric Hyman, Office of Technology Assessment; D. Gale Johnson, University of Chicago; Bruce McCarl, Oregon State University; William R. Miller, University of Nebraska; Paul O'Connor, Forest Service, USDA; Jack van Holst Pellekaan, World Bank; and Luther Tweeten, Oklahoma State University.

A forthcoming companion study, prepared by the International Economics Division (IED) of ERS, examines the current situation and prospects for world food supply, demand, and trade. That study takes an international perspective on the world food situation whereas this one takes a domestic U.S. perspective. This study assumes answers to questions analyzed in the international study, and it summarizes results of that study as background setting for analyzing the potential U.S. food production for world markets. Dick Kennedy served as the IED liaison on the U.S. segment of the study. The general report presented here relies on materials prepared for the international segment of the study by Larry Deaton on world demand for food and by Francis Urban on world supply of food.

Contents

Summary

U.S. agricultural exports are likely to continue to grow, possibly doubling within 30 years. The United States currently exports the product of 40 percent of total harvested acres, twice the rate of the early seventies. Reliance on exports can put farmers at risk to sudden price swings caused by changes in food import policies of foreign governments. The alternative to those sharp swings is to scale back the U.S. farm sector to a size that will support domestic demand only or to adopt policies that counteract the short-term impacts of other governments' food policies.

U.S. agriculture has the capacity to meet expected growth in export demand. Limits to natural resources, energy, labor, and purchased farm inputs are not likely to restrict growth and induce food shortages. U.S. agriculture may not require much more land and water in coming years, but it must retain access to the resources now being used. Various institutional and human factors are more likely to temporarily limit farm production, factors like financial markets, tax laws, income and price support programs, and water rights.

U.S. agricultural policies adopted during the late eighties and beyond will affect how U.S. agriculture continues to operate. If export markets recover from the slowed growth of the early eighties and advance at average rates close to the longrun trend, agriculture will continue to grow. However, if they do not, and thus fail to provide a source of increasing demand for growing domestic agricultural capacity, there are two options: Either rely again on sizable income transfers to avoid another agricultural depression in an agricultural economy about the size of the present one; or scale down the agricultural sector so that it, once again, produces primarily for the domestic market. The latter could result in a prosperous but much smaller agricultural sector than at present; it would also raise serious questions about where the world's food supplies would come from because the United States is now the major exporter.

The chief risk to farmers from a high-export strategy comes from the inherent volatility of export markets. The variability shown by these markets during the past two decades induces boom and bust conditions for farmers and ultimately reduces agricultural output. This has redistributional effects not only on incomes within the farm sector, such as between crop and livestock growers, but also among other sectors including agribusiness, input suppliers, consumers, and trading partners. The volatility of recent experience seems high by the standards set by the relative stability of the fifties and sixties, but is not unusual compared with the volatility of world food markets earlier in this century.

Farmers as individuals have no control over the vagaries of international agricultural trade or international payments, yet their well-being is strongly affected. Most foreign countries regulate their agricultural imports and exports to maximize their own benefit. Such policies circumvent market responses and can induce food surpluses or shortages accompanied by price volatility. To the extent that the adversity is the result of human intervention, such as a decision by a foreign government to import feed to maintain livestock production as an alternative to domestic belt-tightening, or the effects of nonfarm economic conditions on the foreign exchange rate, it will take additional policies to establish reliable markets for U.S. farmers and reliable food supplies for importers of U.S. farm products.

U.S. Agriculture's Potential to Supply World Food Markets

Clark Edwards

Introduction

U.S. farmers look more and more to overseas demand as a basis for growth. That has come about because of relatively slow and steady growth in domestic demand for food compared with faster growing foreign demand, which reflects increased world population and wealth and is affected by foreign governments' policies to upgrade diets. Reliance on exports, while good for many U.S. farmers, especially crop farmers because most of the exports are of crops and crop products, makes the farm sector susceptible to sharp swings in demand. Some of the volatility in international food trade is due to weather and to normal market forces, but many of the sharper swings are attributable to changes in policies of various governments with respect to food imports and exports.

The fortunes of the U.S. farm sector are now tied as much to foreign government policies and domestic nonfarm policies as they are to U.S. farm policies. Reliance on exports caused the farm sector to swing from boom times during the seventies to lean times during the early eighties. So the benefits of continued reliance on exports are accompanied by some risks. We can choose, if we want, to continue to look abroad for farm prosperity; we have the resources to do so. If we choose export growth, it is important that we be prepared to deal with the expected risks.

We now export the production of about 40 percent of all harvested acres compared with 20 percent during the early seventies. Longrun trends suggest that proportion may rise to 50 percent by the turn of the century. If it does, U.S. agriculture has the capacity to meet the growing demands of both domestic and foreign markets at existing or possibly lower real food prices. The difficult question pertains to how to deal with export markets growing faster or slower than the longrun trend, and with volatility.

This report raises the issue of how to think about dealing with shortrun volatility in the farm commodity export markets and with longrun swings from periods of strains on domestic capacity to periods of idle farm resources and low farm incomes. The report examines the implications of alternative futures for farmers, postharvest handlers, input suppliers, consumers, and trading partners.

The analysis is based on past trends, mathematical models of the workings of the farm sector and its interactions with other sectors, and reasonable expectations concerning technical change and other factors. Two models developed in the Economic Research Service were used heavily for the analysis. In addition, expertise within ERS was drawn upon to resolve conflict when the two models disagreed and to fill in the gaps on relevant issues on which both models were silent.

Demand for U.S. Food Products

The larger and more steadily growing part of the total demand for U.S. farm products is domestic. The foreign markets are smaller, but faster growing and more volatile. Hence, demand shifts affecting U.S. farmers are more likely to arise from foreign than domestic sources.

World Food Demand

Over the past three decades, world per capita consumption of food increased slightly in response to higher income and political determination to improve diets and food distribution. Increasing income per capita was relatively less important in developed countries as a source of increased demand for food because, in general, people there are relatively well fed. Most of the increase came from developing countries with newly increasing purchasing power and with policies to deal with hunger and malnutrition.

The effect of population growth on food demand varies with whether per capita purchasing power is maintained and also with demographic patterns such as the proportion of the young and the elderly, who tend to eat less than working-age consumers. World population growth is slowing, implying slower growth in the demand for food. World population grew by around 1.9 percent per year during 1950-70. It slowed to 1.8 percent during the seventies, is around 1.7 percent now, and is expected to be around 1.6 percent during the nineties (*303*).[1] In the next century, if present trends continue, the world population may stabilize.

[1] Italicized numbers in parentheses refer to citations in the References at the end of this publication.

In recent decades, the world composition of foods changed toward more livestock products relative to crop products. This was partly due to decisions by consumers to spend relatively more of their added income for meat. In addition, several countries adopted policies to improve diets by promoting meat consumption. This latter source of change in consumption depends on political decisions that may—but need not—reflect market forces. Government policies were important, for example, in determining change in the levels of food demand during the seventies in the USSR, Eastern Europe, and China. These changes stimulated the world's feed-livestock economy.

Government programs that increase consumption help not only consumers, but farmers as well by expanding the market for food products. But sometimes there is conflict between consumers' and farmers' interests in government programs. An increase in the prices received by farmers, for example, is generally accompanied by an increase in the prices paid by consumers. Some countries' policies support farmers' incomes; if supply management programs are ineffective, then price-increasing policies tend to create surpluses while they reduce consumption. Other countries subsidize consumption; such policies can discourage production by lowering prices thereby reducing farm incomes and creating shortages. Research that helps farmers increase their productivity also helps consumers by increasing the supplies of food and lowering the prices. The prices may fall so low, however, that farm income declines. There are other, noneconomic goals that governments consider. For example, food is sometimes used as a tool of diplomacy. So conflicts arise not only among governments but also within governments about the goals of farm and food policies. Because of these conflicts, one can anticipate continued debate as to whether policies should emphasize increased production to help consumers or limited production to help farmers.

Income distribution tends to be more uneven in countries with lower incomes and lower general levels of education. Income growth does not necessarily correct these problems, so gains in food consumption based on improved income distribution, education, and aid are separate from gains which follow a general improvement in aggregate income. Hunger continues to be a problem in certain parts of the world; how food distribution can be improved is examined by Deaton and others and is not considered in this report (*48*).

During 1980-82, a worldwide recession reduced purchasing power, and per capita food consumption dropped slightly from the record high established in 1978 (*274*). Reduced demand and an increase in carryover stocks resulted in lower prices and reduced income for farmers. This event heightened concern for farmers' income but it eased the concern of the late seventies that increases in world food production might be unable to keep up with consumption. Both the tight food situation of the seventies and the recession of the early eighties may be past, but several factors continue to limit exports of U.S. farm products to various parts of the world: high levels of international debt for many developing nations; high exchange rates with the U.S. dollar, making our exports more costly; and high interest rates that add to the costs of debt servicing as well as to costs of production. These difficulties imply that further and continued volatility can be expected in world food trade.

Even so, prospects are for a longrun, moderate increase in per capita demand. The rate of population growth appears to be slowing slightly and per capita consumption is expected to continue to increase with rising incomes, changing tastes, and improved distribution of food to lower income people. These prospects suggest a rise in aggregate food consumption of perhaps 2.0-2.5 percent per year. At this pace, world food consumption will require a little longer to double next time, about 28-35 years, compared with 27 years for the last doubling. The next question is: Can we reasonably expect world food production to double during the next three decades?

World Food Supplies

World food production increased by 2.9 percent per year during the fifties, slowed to 2.7 percent during the sixties, and dropped to 2.2 percent during the seventies. During the late fifties and early sixties, world food production rose faster than population and production per capita increased, partly as a consequence of policies adopted by various governments around the world to deal with food shortages following World War II. The increase in per capita production allowed for upgrading of diets at favorable prices (*253*).

The slowdown in growth in world food production during the seventies was abetted by bad weather and adverse economic conditions. High energy costs, high interest rates, and inflation followed by recession added to farmers' uncertainty and reduced incentives to expand production. Even so, world food production increased slightly faster than the increase in population during the decade and food production increased moderately. Increases in farmland contributed about 0.4 percent per year to growth in output during the seventies, less than in the previous two decades. The remaining 1.8 percent per year was the result of various technical, social, and geographic factors affecting yield.

If world food production is to double in 30 years to support the increase in consumption implied by population trends and per capita needs, then growth in production will have to increase slightly from the slowed pace of the seventies, to around 2.3 percent per year. This is well below the average rate of 2.6 percent per year for the past 30 years.

Longrun World Food Balance

Do the trends in world food supplies and demands point to a longrun balance in which real food prices are little changed, to demands which outrun supplies and drive real food prices higher, or to plentiful supplies and lower real prices? Imagine a world food situation characterized by two or three decades of growth in the quantities of food supplied and demanded such that there were little change in real food prices. Consumers would spend smaller shares of their increasing real incomes for increasing quantities of food, and farmers would maintain their earnings. On which side of this hypothetical line is a doubling of food production and consumption during the next 30 years likely to fall: toward higher real food prices of benefit to farmers, or toward lower real food prices of benefit to consumers?

Real food prices would rise if demand increased faster—or supply increased slower—than the trends of recent decades. Food supplies would be relatively more scarce. This would adversely affect consumers but would improve the incomes of farmers and of resource owners. It would lead to higher prices for crop products relative to livestock products. The higher prices would reduce the consumption of livestock products relative to crops products.

Alternatively, relative increases in per capita food production due to a further slowing of population growth, increasing availability of land or energy, or advancing technology and institutional innovation, would ease the price of food relative to other goods and services and increase the consumption of livestock products relative to food crop products. However, with food supplies more plentiful, incomes to farmers and to owners of farm resources would be relatively lower.

"There is no shortage of published reports on projections for food production and agriculture," writes Wittwer (*302*). "The general tone is one of pessimism. All raise questions about future productive capacity of U.S. agriculture, the environmental consequences, resource availability, and technological capabilities." The studies referred to by Wittwer were done during the food crisis of the seventies. Since food surpluses and lower prices began to reappear in the early eighties, the general tone has changed to one of optimism with respect to future productive capacity. Reasons supporting first optimism and then pessimism are reviewed in the next two sections.

Prospects for Relative Abundance. World agriculture appears to have the potential to meet growing market demands for food at moderately declining prices received by farmers. Farmers worldwide are likely to expand production, as they have in the past, so that the market-clearing prices received for farm products are close to and occasionally below the unit cost of production. This tendency toward overproduction will contribute downward pressure on the world level of prices received by farmers.

A number of arguments support this view of increasing per capita food production and lower real food costs. The main consideration on the demand side is that world population growth is slowing, and there are major policy objectives in various governments to slow it even further, thus reducing growth in food requirements. This is likely to be more telling than changes in per capita demand due to higher income.

There are several considerations on the supply side. Natural resource development will contribute to increases in production, but most growth in production will be based on improved technology, increased use of purchased inputs, development of regions that are currently below their potential, and adoption of farm policies by various governments to provide incentives to farmers.

Existing natural resources can support substantial increases in the per capita supplies of food over time at moderately decreasing real prices received by farmers (*95*). About half the 7.5 billion acres of arable land in the world is under cultivation (*254*). Continued land development through drainage, irrigation, leveling, breaking up of subsoil hardspans, and better access to isolated land through improved infrastructure, is expected to more than offset the amount of land lost to abandonment or to various nonfarm uses. Some lands recently opened for cultivation in many developing countries are especially susceptible to soil erosion and will need strong protective measures to maintain their productivity (*51*). On balance, the availability of land does not seem to be a critical limiting factor in global food production, although pressures on land resources are very important in some regions.

Much of the land that can be easily cropped with good yields at low development costs, however, is already in use, so an accelerated rate of conversion to cropland likely will result in higher unit costs and reduced yields. Cropland use may expand by about 0.2 percent per year in coming decades without contributing to higher unit costs of production. The expected growth in cropland is below the rate of 0.6 percent per year experienced during the past three decades and below the rate needed to meet food demands if yields do not increase. But the availability of cropland appears to be adequate provided that other resources, technology, and other factors affecting food production become available as anticipated (*253*).

World food production has become highly dependent on irrigation during the past three decades. Forty percent of world production is produced on the 15 percent of the cultivated area that is irrigated. "Most countries, in fact, subsidize irrigation water to encourage production. The low cost leads farmers to apply more water than required for the crops they grow" (*281*). Water resources appear to be adequate; the Food and Agriculture Organization of the United Nations estimates that an additional 130 million acres could be irrigated in the next decade. Even in regions where the quantity of water is limited, there is a good prospect for increasing the efficiency with which water is used through improved management, reduced waste, and reallocation of water among alternative food production uses (*253*).

Energy is a critical input in food production, but the energy used in agricultural production is only 3-6 percent of all commercial energy consumed. The share is 16-22 percent for the food sector as a whole, including processing, transporting, and marketing. The energy shortage of the seventies has abated and energy availability is likely to be sufficient to support growth in agricultural food production—even at moderately decreasing real prices received by farmers—for the rest of the eighties. The biggest shortrun energy threat is additional oil supply disruptions. For developing countries, this is more of a threat to their balance of payments than to their level of food production. However, before the close of this century, higher energy costs again are likely to be a crucial factor in producing food.

The nonfarm sector can increase the quantities offered to farmers of purchased farm inputs, including chemicals and machinery. The price farmers pay may increase as their demands increase, but the real prices are not expected to diverge much from prices paid by buyers in other industries, such as manufacturing and construction, for similar products. The nonfarm sector will continue to improve the efficiency of transporting, processing, and distributing food products to final users. A larger and sustained public and private investment has been made in modern infrastructure—roads, bridges, storage facilities, communications systems, market services, electricity and power, research, and education—to support agriculture. The quality of this infrastructure varies. In developed regions, small additions to infrastructure generally will support more than the projected growth in food production. In other regions, like Sub-Saharan Africa, insufficient infrastructure can limit the rate of agricultural growth for some time to come.

There are prospects for increasing productivity of existing resources through technological advance, including mechanization, fertilization, and biotechnologies. The value of human capital can be increased further through education. The full benefits of higher yielding crop varieties and other technical advances now available are yet to be felt, and additional technologies are expected to increase crop and livestock yields further over the next few years.

Developing countries experienced rapid increases in food production during the past three decades. These countries still have a large potential for growth in food production through improved access to resources, innovations in institutional arrangements, technologies appropriate to their agricultures, development of underutilized regions, and implementation of policies favorable to agricultural growth. Policies in many of these countries have tended to promote food consumption rather than production.

Agriculture is resilient, according to Paarlberg, and can adapt to widely changing needs (*186*). When a limit to growth in food production is met with respect to a specific resource used for a specific commodity in a specific region, then regional shifts and institutional adaptation can accommodate large changes in food production using presently available resources and technology. Lutton demonstrated that substitutions among resources and among products add flexibility to producer and consumer responses, which has the effect of easing world food supplies as limits to growth are approached (*150*).

Prospects for Relative Scarcity. The alternative view cannot be ruled out, however. There may be decreasing per capita food supplies and higher real food costs. Food demands could accelerate to a level above that associated with constant real prices in response to continued population pressures if birth rates were higher or death rates lower than anticipated. Demand could increase faster than indicated by recent trends should the world economy accelerate. An acceleration of food distribution programs to disadvantaged countries would increase aggregate consumption. So would a redistribution of income within a country that increases the relative purchasing power of its lower income population.

Shifts in consumer preferences for more meat products relative to crop products, such as have taken place in some of the more prosperous developing countries, induce a demand for more feed grains relative to food grains. The changes in agricultural production required to accommodate such shifts increase the agricultural resources used to feed a given population. Changing tastes and new food-processing technologies led to an expanding market for oil crops for both food and feed uses and placed further demands on agricultural resources.

Food production might fail to increase fast enough to avert upward pressure on real prices. Growth in world food production slowed during the seventies, suggesting diminishing returns as additional variable inputs were added to fixed natural resources. The loss of soil fertility from erosion, salinity, compaction, desertification, overgrazing, acidity, and waterlogging affected agricultural production in many developing countries. The new lands opened for cultivation in many developing countries are particularly susceptible to soil erosion. Water constraints limit growth in some regions; and even when expansion is feasible, the capital requirements are high and projects take a long time to implement. Environmental degradation and pollution pose increasing threats to resource use. A shortfall in supply due to sudden loss of access to land or water could prove to be far more difficult to accommodate in the short run, and therefore more damaging to the well-being of people, than an explosion in the population growth rate.

Meeting world food requirements in coming decades appears to depend more on increasing the productivity of natural resources than on increasing the quantity used. This involves technical and social change that is adopted slowly in many countries because of the education and skill of potential adopters and also because not all change is seen as progress.

Global Balance. There is solid support for a view of relative food abundance and also support for the opposite view of relative scarcity. Neither extreme abundance nor extreme scarcity is very likely. The trend of the last 30 years has been close to the middle, but shows a slight tendency toward plenty. Johnson described a trend of moderately increasing per capita food supplies and slowly (but erratically) decreasing real food prices (*120*). The increasing value added to food markets by the nonfarm sector after harvest has widened the gap between prices paid by consumers and prices received by farmers. The evidence suggests continued moderate increases in per capita consumption and downward pressure on real prices received by farmers over the next three decades.

This is not to say that plentiful supplies of cheap food are certain for the next 30 years. Rather, it means that the probability is high for continued moderate reductions in real food prices. The actual outcome will depend heavily on whether certain things that can happen (which are discussed in this report) are made to happen during the eighties and nineties by means of private and public policies.

This picture of the future involves a growing nonfarm economy that creates adequate employment and rising real incomes. It calls for consumer expenditures for food to be a decreasing share of income, and it includes upgrading of diets, such as more livestock products relative to crop products. It calls for the farm sector of the economy to grow more slowly than the nonfarm sector and to comprise a declining share of the world economy. It calls for gains in capacity to rely more on social, technical, and regional changes that increase yields than on the development of natural resources. It calls for public and private policies to expand the capacity of agriculture and to maintain incentives for farmers. And at the same time, it calls for policies to promote regional trade and distribution to assure that consumer needs are fulfilled.

If the world food supply becomes more limited than indicated in the previous paragraph, with population pressing against the capacity to grow food, the export markets for U.S. food products would grow faster. Prices received by farmers, according to this picture, will be higher than they would have been. The higher prices would improve farm incomes and also increase the returns to suppliers of farm inputs, particularly landowners. Consumer prices will increase, which will reduce domestic per capita consumption and reduce the rate of growth in the services of agribusiness for processing, distributing, and marketing food products.

On the other hand, if the world food supply becomes more plentiful, export markets for U.S. food products would grow more slowly and U.S. agriculture may develop excess capacity. Prices received by farmers, according to this picture, will be lower than they would have been and, if present farm programs are still in place, extensive financial assistance will have to be provided to maintain farm income. Consumers will benefit from lower real food prices and consumption of livestock products will increase relative to crop products. The marketing sector will benefit from an increased volume of trade, but farmers and input suppliers will be disadvantaged.

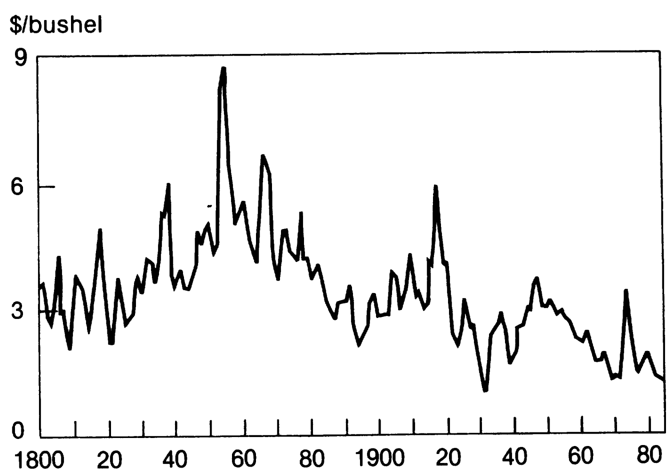
The different scenarios have implications for the distribution of income within agriculture as well. Under a tighter world food situation, feed grain and oilseed prices will be relatively higher, thus improving the income of crop growers but reducing the income of livestock growers.

The longrun trend in real prices received by U.S. farmers has been downward in the United States for more than a century (fig. 1.) This reflects strong growth in agricultural productivity relative to growth in the demand for foods and it has been influenced by opportunities for foreign trade. Despite this decline in real prices received, farm incomes improved. Lower prices do not mean lower farm incomes if productivity improves and production per farmer increases.

The price trend has not been steady, however. Prices received by farmers escalated during and following World War I, then declined during the twenties and thirties, and escalated again during World War II. Prices (adjusted for inflation) declined again during the fifties and sixties but escalated during the food crisis of the seventies. The likely prospect is for the gradual

Figure 1

Real Wheat Price (in 1967 Dollars)



downtrend in real prices received by farmers to continue during coming decades, subject to periodic interruptions. One of the reasons that real prices received by U.S. farmers are expected to decrease in coming decades is that real world food prices are expected to decrease and U.S. prices are affected by trends in world prices. Another reason is that U.S. agricultural capacity has tended to grow faster than the domestic and export markets.

Prices paid by farmers, particularly for energy intensive inputs, are likely to increase in coming decades. Therefore, a continued decrease in the parity ratio—the ratio of prices received to prices paid—is expected. The longrun implications of this trend are not calamitous for efficient farmers, but the shortrun implications will raise important policy issues during periods of lower farmer incomes.

The historical downward trend in the parity ratio provided a basis for farm price supports during the thirties when agriculture was considered part of a closed economy. The internationalization of agriculture since then changed the basis for farm policy and suggests a reconsideration of the role of the parity ratio in farm policy. The foreign consideration is that if the United States is to expand its export markets, it must match the downward trend in world prices. The domestic consideration is that the structure of the farm sector is different now than it was 50 years ago when present programs had their beginnings.

Fifty years ago, when most farm production was on diversified family farms, price supports of selected commodities boosted the incomes of a broad range of farmers whose incomes were low relative to nonfarm incomes. Now, after 50 years of farm specialization and growth, only 5 percent of the farms produce half the farm output while half of the farms (the smaller ones) produce only 5 percent of the output (*270*). Although the average farm income of the smaller farms continues to be low, many of these are part-time farms with substantial nonfarm income. The farms now most vulnerable, and perhaps most in need of a safety net, are the smaller of the commercial, family farms.

The best level of price support and income protection is an important issue. Because of changes in the size distribution of farms, specialization, and access to nonfarm income, those who now need financial assistance the most no longer tend to be helped as much by commodity programs (*144*). In addition, price supports tend to help most of the farmers whose commodities are directly supported. For example, when a farmer produces both corn and hogs, price supports on corn improve overall income. But when one farmer specializes in corn and another in hogs, price supports for corn result in higher feed costs and perhaps lower income for specialized hog farmers. The farm programs that worked reasonably well during past cost-price squeezes apparently will work less well in accomplishing the same goals in the future. If growth of agricultural export markets is to continue, domestic price policies will have to make sure that U.S. farm products are priced competitively in world markets.

The analysis in this report of the U.S. farm supply response to changing world food markets follows Urban in assuming that moderate world plenty is more likely than scarcity (*253*). Hence, the basic scenario recognizes the gradual downward pressures on prices received by farmers, and upward pressures on prices paid. However, the evidence supporting this view, while convincing, is not overwhelming. Deaton (*48*) demonstrates that the conclusions one draws with respect to the trend in real food prices depends on the choice of commodities and on the time period examined. Therefore, the implications are also examined in this report of the alternative assumption: that the next three decades will be characterized by moderate food scarcity and gradually rising real food prices.

Shortrun World Food Balance

It is possible to have longrun global balance in the world food situation and at the same time experience shortrun fluctuations or imbalances as well as persistent regional imbalances. What may prove to be more important to U.S. farmers and consumers than a possible, small, downward tilt in the longrun trend for real food prices are increasing shortrun swings from temporary scarcity to abundance and widening regional disparities. World prices of some commodities have become more volatile in recent years and prospects for increasing regional imbalances of production relative to local consumption, increasing reliance of formerly self-sufficient countries on world markets, and possible increases in government intervention point to an increasing volume of world trade, shifting patterns of trade flows, and a continued relatively high level of world food price variability. Some countries have changed from importers to exporters while others face increasing food deficits. Therefore, additional alternative futures are considered in this report. The following section examines whether widening regional imbalances might increase the volume of world trade; the one following that examines whether trade patterns and world food prices might become more volatile from one year to the next.

Regional Imbalances. World trends cover up regional variations. World food production about equals world consumption, but regional disparities are widening. "World economic growth has altered the pattern, direction, and volume of world trade", according to Mackie (*152*).

Population is growing below the world rate in most of the developed countries, and food production is growing above the world rate. With the exception of Japan, where food production slowed during the sixties and seventies, production per capita is increasing and these countries are net exporters. Among the developing countries, population is growing well above the world rate. Production per capita is increasing substantially in East Asia, Argentina, Indonesia, Southeast Asia, and Brazil but is decreasing in Sub-Saharan Africa, Egypt, parts of South Asia, and parts of South America. Among the centrally planned countries, population and production are both growing below the world rates but production per capita is increasing.

Some of these disparities reflect longrun regional situations. For example, Sub-Saharan Africa's rapid growth in population and slow growth in food production are likely to continue for some time. A combination of environmental, political, and economic forces is behind the serious longrun food problem in Africa and they have been compounded by drought (*95*). Sub-Saharan Africa's production per capita is likely to continue to be limited by natural resources, an unstable climate, lack of investment in agriculture and infrastructure, lack of nonfarm economic development, inappropriate agricultural policies, and political instability. Soil deterioration is severe in Nepal, Indonesia, many parts of Africa, and on the cultivated lands of the Andes Mountains in South America.

A study of 106 non-Communist developing countries noted worsening trends in food self-sufficiency for 73 countries, accounting for 45 percent of the population and 58 percent of the gross national product of all 106 countries (*237*). These countries include most of the world's poorest and smallest economies and are scattered over three continents and on the islands of three oceans.

Some of the regional disparities are the result of deliberate actions, such as to improve diets. Japan and the USSR moved from food grain economies toward feed-livestock economies. Such policies make the world food situation tighter because livestock production requires more resources per capita than food crop production. During the seventies, Japan's livestock production increased by more than 5 percent per year while its crop production dropped by about 1 percent per year. The USSR increased livestock production by nearly 2 percent per year during the seventies while crop production increased little (*274*). These countries relied on imports to maintain their expanding feed-livestock economies. They imported feed grains from the United States, where crop production expanded rapidly while U.S. livestock production increased about in proportion to the growth in population. China accelerated growth in food production while slowing its population growth. Food production per capita in China changed from decreases during the fifties and sixties to increases during the seventies. This resulted from adoption of available technology and of increased incentives from the government. Growth in meat production exceeded growth in the available feed supply and China became a major importer of grain (*301*). The developing countries, the USSR, and China are expected to continue to be major food importers during coming decades (*297*).

Regional trends suggest an increasing volume of world trade in food products in coming decades, both in volume traded and as a percentage of world production. During the past three decades, the volume of world food trade increased by 5 percent per year. Only a small portion of the world's food is traded internationally since most nations are largely self-sufficient in their major foodstuffs. Improved diets, specialization in commodities for which there is a comparative advantage, and export either for the purpose of acquiring foreign exchange or to draw down domestic surpluses, imply less self-sufficiency and increasing dependence on world trade. The persistence of food deficit regions implies the need for counterbalancing food surplus regions, such as the United States.

Despite relative increases in meat consumption, the world's population continues to rely upon cereal grains as the principal source of both calories and protein (*48*). The United States and Canada likely will continue to dominate world grain exports in coming decades, with Australia, South Africa, Argentina, and Thailand also contributing. Developing countries will import about two-thirds of this and centrally planned countries most of the other third. World trade in high-value crops, such as fruits, vegetables, livestock products, and processed grain products, is increasing relative to bulk products such as grain and oilseeds (*179*). However, the U.S. share of world trade in high-value food products has shrunk while its share of bulk products has expanded.

Temporal Imbalances. World food markets were volatile during the seventies compared with the relative stability of the fifties and sixties and continue to be volatile during the eighties (*165, 166, 178*). Increasing dependence on world markets makes both producers and consumers more vulnerable to adverse conditions and increases the pressures for policies that protect them from uncertainty. The reasons for the increase in fluctuations include weather, regional disparities, and intervention by governments. The degree of variation in world food production changes little from one decade to the next, but the geographic location of variation may shift. For example, production in the United States, South Africa, and India became more variable during the seventies than it was during the fifties, while production in China, Japan, and Argentina became less variable (*253*). Random variation in world food production in coming decades is projected, for the purpose of this study, to be similar to that of recent decades. Changing levels of trade and of institutional arrangements affecting trade, even with a continuation of past volatility in production, can lead to changes in the volatility of world prices and of regional per capita consumption. This study focuses on changes in the variability of world food prices and regional trade, not on changes in the variability of aggregate world food production.

Government intervention during the seventies in trade agreements, subsidies, tariffs, embargoes, and other trade barriers disrupted trade flows and affected prices. These actions increased the volatility of world food markets above the level expected from weather and trade patterns of the fifties and sixties. U.S. food prices were relatively stable during the earlier period because government programs maintained prices received by U.S. farmers above world prices and therefore free from world price disturbances. But U.S. prices were again competitive with world prices during the volatile seventies.

Perhaps the most important source of increasing variability in world food trade and prices is the intervention of governments (*120*). It is characteristic of the intervention itself to be volatile, in that policy reversals are common. Blandford and Schwartz found world food prices to be volatile because of (1) shortrun fluctuations in production of developing and centrally planned economies and (2) the unresponsiveness of market participants to shortrun changes in world price (*21*). Wheat production and wheat prices in the Eastern Hemisphere have traditionally been more variable than in the Western Hemisphere. Were there no trade between the two regions, the market for farmers in the Western Hemisphere would be relatively stable and that in the Eastern volatile. With free trade, the two regions would share fluctuations in price and quantity; price fluctuations would decrease in the East and increase in the West. If governments in the Eastern Hemisphere adopt protective policies to meet domestic grain needs annually, regardless of cost, and if governments in the Western Hemisphere adopt free market policies, then a food shortage due to adverse weather in the Eastern Hemisphere would be transferred entirely to the Western Hemisphere. Fluctuations in price and quantity would then be felt in the Hemisphere that was stable under isolation. Decisions by governments to protect and to stabilize domestic markets, or to impose and then remove embargoes, add to the instability of world food markets.

U.S. farmers experienced an unusual period of price stability during the fifties and sixties. Prices received by farmers trended downward during that period, but the annual fluctuation was moderate compared with prices before or since. The prospect is for prices received by farmers to continue to be more volatile than during the unusually stable fifties and sixties.

There are benefits to price changeability. It permits markets to signal for resource reallocations and it eliminates inefficient firms from the industry. Farmers benefit from the higher average price level that usually accompanies uncertainty. However, extreme fluctuations can drive firms out of business that would have been efficient in more normal times, increase concentration of production, and induce windfall gains and losses. A high degree of price volatility tends to reduce the efficiency of agriculture by causing risk-averse farmers, through informal insurance strategies (like diversification) to produce less than they otherwise would. This reduces supplies to consumers and results in food prices being higher than they would have been if farmers were more certain of future prices. A high degree of uncertainty can result in a net loss to society. To the extent that food price stability is in the public interest, it may be desirable to find ways to share this risk.

An issue of the late eighties and nineties will be the extent to which government programs maintain relative price stability as an adjunct to dealing with the problem of maintaining reliable export markets for U.S. farmers. At the same time, importers of U.S. products want a reliable supply. Government price stabilization usually involves, in addition to orderly export and import marketing policies, carryover stock management. Tools other than stocking include price or quantity controls, variable subsidies, and excise taxes. While intervention by a government can stabilize its internal market, it is likely to increase price volatility in the rest of the world.

Stock management in the past had price support as an objective. Stockpiling to maintain higher prices for farmers will again result in either burdensome surpluses or severe supply management programs. If U.S. stocks are to be manageable, and if U.S. agriculture is to be competitive in world markets, then stock management must focus instead on stabilizing prices around the gradually decreasing world level.

Stock management programs that stabilize prices can be ineffective if they seek to stabilize prices within too narrow a range. Private speculators will be driven from the market, and market signals will not be felt by producers and consumers. At the same time, stock management programs must face the twin problems of a run of bumper crops, which leads to burdensome surpluses, or a run of short crops which reduces stocks to zero and permits price escalation anyway (*194*).

The world market for U.S. food exports in the coming decades is likely to be characterized by increasing per capita consumption, a continued high level of volatility around a moderately declining trend in real food prices, increasing prices paid by farmers relative to prices received, and an increasing volume of world trade relative to production. These trends have implications for U.S. farmers and consumers. If domestic food prices match world prices in coming decades as U.S. farmers turn increasingly to export markets as a source of growth, then U.S. food markets would share the longrun down-drift in prices received and feel the effects of future disruptions in word trade. But one cannot rule out that per capita food supplies could, instead, become relatively limited due to faster than anticipated increases in demand or to slower increases in supply; or that governments could stabilize world markets. U.S. farm policy needs to be flexible enough to adapt.

The future is uncertain, so this study is not confined to the outcome considered most likely. Instead, it examines the implications of alternative futures. Two questions which have been discussed are: Will real food prices increase or decrease? and, will prices become more or less volatile? Out of these two dimensions, four alternative futures can be described: (1) decreasing real food prices with price stability; (2) decreasing real food prices with price volatility; (3) increasing real food prices with price stability; and (4) increasing real food prices with price volatility. This report considers the implications for U.S. farmers and consumers of each of these four outcomes.

U.S. Agricultural Trade

U.S. agriculture is solidly linked to the world economy. Through that linkage, social, political, economic, and natural events elsewhere influence domestic farm production and income. U.S. agricultural exports have accounted for nearly one-fifth of total world agricultural trade since 1973. During 1982, 88 percent of the soybeans in world trade were exported from the United States, 56 percent of feed grains, and 40 percent of the wheat. The United States held about one-third of the world's wheat carryover stocks and 60 percent of the coarse grain stocks. Wheat, corn, and soybeans account for more than half the value of U.S. farm exports. Therefore, even though exports are important to the growers of several other commodities, the implications for the aggregate income and production of U.S. agriculture of changes in the world food situation can be estimated by examining the exports of only a few principal crops.

Two out of 5 acres of U.S. cropland are harvested for export markets. A major share of the income to the crop sector depends directly on exports. Income to the livestock sector is affected indirectly through feed costs. The growth and stability of U.S. agriculture have important consequences for world food markets. The converse is also true: the growth and stability of world food markets have important consequences for U.S. agriculture.

From one viewpoint, the United States entered this market relationship actively—grass roots organizations have spoken in favor of (for example, growers of commodities in surplus) and against (for example, resource conservationists) increases in exports; and government policies have, at different times, contributed to both increases and decreases in exports. However, the United States has tended to play a relatively passive role as a residual supplier—expanding exports, increasing production, and drawing down stocks when the world food supply is tight; and contracting exports, decreasing production, and building up stocks when the world situation eases. In relatively stable and growing world food markets, such a role can be played with a minimum of government intervention. However, when world prices become erratic, the resulting buffeting of U.S. agriculture induces those who are disadvantaged to plead for protection.

The last time agricultural exports rose to a dominant position in U.S. food markets was during the expansion related to World War I. By the early twenties, 1 acre in 5 was harvested for export. These markets closed during the twenties and thirties and by 1940 the United States exported almost no agricultural products. Following the buildup for World War II, U.S. export markets grew unsteadily until, by the late sixties, 1 acre in 5 was again harvested for export. After World War I, exports were mostly for industrial and nonfood uses: cotton, tobacco, hides, and tallow. The resurgence of exports following World War II, especially wheat, was oriented more toward food. Subsequent export growth, during the seventies, shifted emphasis to livestock feed, especially corn and soybeans. The shift from food to feed reflects a change in emphasis from aid and concessionary sales to satisfying the market demands of countries with rising purchasing power.

During the fifties and sixties, while export markets for U.S. farm products were growing, U.S. agriculture experienced problems of surplus production. Fewer cropland acres were required each year to meet domestic needs because of advancing technology. While more acres were devoted to exports, other acres were retired from crop production under various supply management programs. By 1969, when 61 million acres were harvested for export, 58 million acres were diverted from production under government programs (*74*). U.S. agriculture had sufficient retired cropland to approximately double its level of exports. And that is what happened even though the acres released from diversion were not necessarily the same acres used to grow export crops. As more land came out of retirement during the early seventies more of the harvest was for export. Much of the expansion during the seventies was on land that had been idle, fallow, or used for growing crops not excluded by government programs. There was an increase in double cropping and additional conversion of pastureland to cropland. There were reductions in the cropland harvested for domestic markets, and there were regional shifts in the location of production.

The growth in U.S. export markets during the seventies was due as much to supply push (the availability of retired cropland and other farm resources and changes in price policy to be more competitive in world markets) as to demand pull (expanding markets in the USSR and China) (*122*). The United States is an exporter of primary products from its high-technology agriculture and an exporter of high-technology industrial products such as complex machinery and electronic goods. It is an importer of various raw materials and mid-technology products. The declining value of the dollar in the early seventies helped expand both farm and nonfarm exports during the decade just as the rising value of the dollar helped to limit exports in the early eighties (*145*).

During the seventies, the quantity of U.S. agricultural exports rose at an average annual rate of about 8 percent. This pace was not sustainable in the long run without sharp changes in relative prices, consumers' well-being, and agricultural structure; it implied a doubling of exports every decade. The acres in reserve had been released during the early seventies and absorbed into production; they were no longer a source for growth. The more intensive use of cropland raised concerns about soil conservation and environmental quality. Resources other than land were needed, and the increased demand for inputs by farmers caused them to increase their purchases of farm inputs despite increases in prices paid. Increased exports resulted in tighter domestic markets and less food at higher prices for domestic consumers. The proportion of cropland harvested for export increased to 40 percent by the end of the decade from 20 percent at the beginning. In 1980, 68 percent of the rice acreage was harvested for export, 65 percent of the wheat, 62 percent of the cotton, 53 percent of the soybeans, and 30 percent of the corn.

During the early eighties, the demand for U.S. exports weakened. The value of exports fell by 21 percent during 1981-83; about half the reduction came from lower prices, the rest from reduced quantities. Corn exports peaked at 61 million metric tons in 1980 and then fell to 47 million in 1983, a drop equivalent to the harvest of 5 million acres.[2] Wheat exports peaked at 46 million metric tons in 1982 and then fell to 39 million in 1983. Soybeans and products peaked at 33 million metric tons in 1982 and fell slightly in 1983.

Nominal prices received for farm exports about doubled during 1973-74, held steady until 1978, then rose again moderately during 1979-81. Prices were generally lower for most major farm exports in 1983 than in 1982, but were higher again in 1984. Sluggish worldwide economic growth contributed to the slowing demand for U.S. farm products, and a strengthening dollar in world markets added to the prices paid by importers. In addition, government policies (mostly by the United States, the Soviet Union, and the European Economic Community) led to changes in trade flows. The Soviet Union improved the feeding efficiency of domestic grain and thereby reduced its demand for imports. World production of wheat and soybeans rose, so the need to import these crops from the United States was reduced. Several importing nations, particularly those with heavy indebtedness at a high rate of interest, had balance of payments difficulties that limited their ability to import. The growth during the seventies of markets for U.S. agricultural exports came to an end during the early eighties not from the U.S. supply side, but from the export demand side.

The loss of U.S. export markets during this period was not unique to agriculture. During the seventies, the value of farm exports rose by 16 percent per year, about in line with growth in nonfarm exports; exports as a share of Gross National Product doubled during this period. About one dollar in five of total U.S. exports is for agricultural products.

The United States is not only the major exporter of agricultural products, it is also a major importer, exceeded only by the European Economic Community and the Soviet Union. Eighty-five percent of U.S. food consumption is from domestic sources, the other 15 percent is imported. The value of U.S. agricultural exports has exceeded imports since 1960. During the early eighties, the balance of agricultural trade was around $25 billion. This trade balance is available as foreign exchange with which to acquire nonfarm imports, support capital outflows, and meet U.S. obligations for payments. Exports provide expanding markets for domestic products and increasing levels of foreign exchange.

Imports contribute to deficits in the balance of payments and they substitute for goods and services that might have been produced domestically. When the dollar becomes more expensive in terms of foreign currency, not only are exports reduced, but imports are increased. However, the view that exports are beneficial and imports detrimental to an economy oversimplifies the issue. Imports are a necessary part of foreign trade. We have to import if we expect to export. Exports can draw down domestic supplies, make domestic markets tighter, and strengthen domestic prices whereas imports can weaken domestic prices. Imports can increase efficiency by bringing to domestic markets items for which other countries have a comparative advantage. Such imports are called supplementary, or competitive imports. They include certain meat products, fruits, and vegetables. Imports also provide the domestic economy with food products we do not grow domestically, such as bananas, coffee, and tea. The latter are called complementary, or noncompetitive imports.

The quantity of noncompetitive food imports has changed little since World War II and the year-to-year variations have been small. Competitive imports have been growing and fluctuating. Competitive imports grew at an annual rate of about 7 percent during the late sixties and early seventies. This period of growth in imports was associated with: growth in domestic demand for all food products; domestic inflation at a time when prices of imported foods were relatively steady; and, for the early part of the period, acreage retirement under farm price support programs. Import prices began to rise during the seventies at around 7 percent per year. Competitive imports showed considerable year-to-year variation around the midseventies, but no further upward trend until the mideighties.

Exports and competitive imports have both increased and become more uncertain. Exports rose faster than imports so that until the early eighties there was an increase in real net exports.

A resurgence in exports depends on several factors. (See "U.S. Supply Response to Foreign Demand," a later section of this report, for a discussion of factors affecting supply.) Demand factors that would lead to a resurgence include: an acceleration in world population and income, a setback in the expansion of world food production, a less expensive dollar, and govern-

[2]A metric ton equals 2,204.62 pounds.

ment policies and institutional arrangements (undertaken either by the United States or by others) that boost exports through changes in monetary policy, tax laws, quotas, embargoes, subsidies, promotions, or aid. Several of these factors appear adverse at the present time. For example, the U.S. dollar has appreciated relative to the basket of currencies representing the importers of U.S. farm products. During 1978-84, the increased value of the dollar raised the cost of U.S. products to importers at an average rate of 5 percent per year in real terms (fig. 2). This compares with a decline in the real cost during most of the seventies when markets for U.S. exports were expanding rapidly.

Longrun prospects are that farm product exports will resume their upward trend, but at a slower pace, possibly 3 percent per year compared with 8 percent during the seventies (*95*). Given the dependence of U.S. farmers on export markets, particularly for wheat, corn, and soybeans, one of the most important factors that will determine farm income in coming years is the level of, and stability in, food export markets.

Changes in U.S. agriculture's relationship to the world food economy have changed the basis for U.S. farm policy. During the thirties, when the forerunners of today's U.S. farm programs were put in place, the concern was for a disadvantaged, lower income, fundamental agricultural sector. Agricultural exports were not significant. Consumers had much to gain by assisting the agricultural sector in a closed economy. When the agricultural industry was found to be disadvantaged through no direct fault of farmers, programs were adopted to transfer income from the nonfarm to the farm sector. The cost of these programs was met by higher consumer prices and by taxes. The benefits accrued mostly within the domestic economy to consumers (who gained a dependable food supply from an increasingly efficient domestic agriculture) and to farmers (who received transfer payments or prices higher than free markets would yield). Landowners benefited from higher land values.

Figure 2

Weighted Real Exchange Rate for Farm Exports (April 1971 = 100)

Source: *Agricultural Outlook,* May 1985 and earlier issues.

Fifty years later, the improved incomes of the farmers who produce most of the farm products, the changing structure of agriculture toward fewer and more efficient farms, the dependence on financial markets, and the dependence of agriculture on increasingly volatile export markets suggest a reorientation of agricultural policies. The older objective of higher prices to protect farm income conflicts with the newer objective of lower prices to maintain and expand exports. World food prices, after adjustment for inflation, are expected to decline moderately during coming decades; and domestic agriculture will have the potential to produce more than enough for domestic and export markets at anticipated prices. For these domestic and foreign reasons, real prices received by U.S. farmers in coming decades are expected to continue their longrun decline. Taxpayers who tacitly agreed to farm subsidies in a closed economy may question supports for crops that are mostly for export. In addition, the volatility of the world food price could be reflected in U.S. markets. If U.S. agriculture is to be a reliable supplier of food to the world, then new policies to protect it from buffeting in an open economy must be considered as replacements for the old policies designed to assist a low-income industry in a closed economy.

Whether the markets for U.S. exports expand or contract, or whether they become more stable or volatile, has important implications for the efficiency of the agricultural system and for the distribution of income among farmers, consumers, the domestic nonfarm sector, and U.S. trading partners. Changes in the world food situation, therefore, have important implications for U.S. agricultural policy. In turn, actions affecting U.S. agriculture taken during the remainder of the eighties will have consequences for what the U.S. and world food situations will be in coming decades.

Domestic Demand for U.S. Farm Products

From the thirties through the sixties, farmers looked to a growing domestic market as the basis for agricultural growth. This orientation changed during the seventies. Fluctuations in export markets have had far more impact on farm income and production than have the moderate changes experienced in the domestic market. Even so, the domestic market now absorbs about 90 percent of the livestock output, and 60 percent of the output of harvested cropland. Nonfarm businesses closely linked to agriculture (agribusiness) account for more of the value added to food products than does farming and for more of the jobs related to food and fiber processing and handling. The nonfarm business and the consumer sectors of the U.S. economy are intimately linked to agriculture and therefore have a stake in world food supplies and prices, and in U.S. farmers' adjustments to world conditions.

Clark Edwards

The size of the U.S. market for farm products varies with population, per capita income, income distribution, the price of food relative to nonfood items, relative prices among food items, and tastes. It also depends on the competition of export markets for domestic food supplies.

Changes in population explain more of the variation in the size of the domestic market for food products than do changes in consumption per capita. U.S. population growth is slowing; the annual rate of growth is down to 0.9 percent and is expected to drop further, to around 0.6 percent, by 2000. It may be close to zero by the middle of the next century, according to projections of the U.S. Bureau of the Census. The domestic population may reach its maximum during the next century at a level one-third larger than the present level. If per capita food consumption remains constant, population growth will increase the U.S. market for farm products by only 20 percent over the next three decades. Farmers can no longer look to a growing domestic population as a major source of growth in the demand for food.

Real income per capita is expected to rise over the next three decades, and the higher one's income, the more one is likely to spend for food. However, people tend to be already well fed in developed economies, so a further increase in per capita income might lead to only small further increases in food purchases. Changes are more likely to be in quality, or in value added after the food products leave the farm, than in additional volume of foodstuffs from farmers. The relation of income to food expenditures in the United States implies that, as the economy grows, agriculture also grows, but more slowly because people spend most of their additional income on things other than food. Agriculture accounts for a declining share of the growing total economy.

The cost of food relative to the purchasing power of an hour's work has fallen at an average rate of about 1.5 percent per year in this century. The decline has not been steady, however. Real food prices fell rapidly during the thirties, rose during the forties, and fell again during the fifties and sixties. There was an increase in real food prices during the seventies which reflected the accelerating exports and tighter domestic food markets. When real prices for food rise, people tend to buy less but they devote a larger share of their income to food. During the early eighties, the real price of food returned about to the level of the midsixties. The increase in real food prices during the seventies may prove to have been a temporary interruption of the long-run downtrend.

If world food supplies become more plentiful, then consumer prices will decrease, but not at the same rate for all commodities. The changes in relative prices will induce changes in the mix of commodities consumed. For example, the demand for grain for food is relatively inelastic, so if supplies increased, the resulting price decreases would induce relatively small increases in consumption. Alternatively, the demand for meat is relatively elastic, so if supplies increased, the resulting price decreases would induce relatively larger increases in consumption. Consequently, if there were comparable inducements to farmers to increase the supplies of both products, prices for grain would fall relative to prices for meat and grain would be considered a better buy than it had been. This would induce farmers to shift toward less grain and more meat production. As a result, per capita consumption of meat would increase relative to grain used for food. Therefore, an increase in world food supplies could lead to relative increases in the quantities of livestock products sold and to relative decreases in the prices received for crop products.

An increase in the domestic demand for food affects U.S. agriculture differently than an increase in export demand because of the different proportions of crop and livestock products in the two markets. An increase in domestic demand affects all commodities more or less equally whereas an increase in foreign demand is mostly for crops, particularly wheat, corn, and soybeans. Increased export demand improves the income of crop producers, but, because of the impact on feed costs, it can adversely affect livestock producers. Slower domestic growth relative to exports, therefore, implies redistribution of income within agriculture favoring crop producers unless changes are made in the competitiveness of U.S. livestock products in world food markets.

The net implication of the trends in population, income per capita, income distribution, real food prices, relative food prices, tastes, and political strategies is that the domestic demand for food will rise by less than one-third during the next three decades, with most of the increase associated with population growth. Domestic agriculture can meet these demands by expanding production for domestic use by around 1 percent or less per year. The productivity of agricultural resources has been growing faster than the domestic market, so fewer farm resources are needed each year to meet domestic needs. If U.S. consumers were the only market for U.S. food products, U.S. agriculture would have surplus capacity, low income, and continued outmigration of people and resources.

A number of nonfood uses can absorb resources used by farmers. Some of these are within traditional agriculture, such as fiber. Others are not traditional, such as production of gasoline substitutes from farm products (*28*). Yet others are nonfarm activities such as forestry, mining, and numerous residential, industrial, and urban uses of resources also used by farmers. It is technically feasible that some of these uses of farm resources—biomass for energy, for example—could absorb a large share of the potential output of U.S. agriculture. Such large-scale changes are not now considered economically efficient (*306*). Therefore, further expansion of export markets appears to be the basis for continued growth of U.S. agriculture.

Farming is only part of the total food production process. In the United States, about 3 million people are employed on farms; another 20 million are engaged off the farm in providing additional goods and services—in the form of processing, distributing, trading, and indirect services to those directly involved—which add to the final value of food products. Most of the agribusiness jobs are associated with providing food and other farm products to domestic consumers, fewer than 1 million jobs are associated with food exports (*272*).

The incomes of the persons in agribusiness who work for domestic food markets are affected differently than the incomes of farmers or of the persons in agribusiness who work for export markets. A large amount of value is added to food products on their way from the farm to domestic markets compared with the relatively little processing or packaging involved in most exports. This means that demand for an additional $1 of farm products (at the farm gate) has far more impact on national income and employment if that farm product is for domestic consumption than if it is for export.

The prospect for relatively slower growth of domestic than foreign markets therefore has potentially important distributional consequences. Relatively rapid growth in export markets provides income and employment to farmers (particularly growers of grains and oilseeds), to those who supply inputs to farmers, and to those who handle, process, and transport farm products for export. But the crowding out of domestic markets when exports increase implies a relative tendency toward increased unemployment, idle plant capacity, and higher unit costs in the marketing sector, unless more processing, packaging, and other values are added by agribusiness to U.S. food exports.

U.S. Supply Response to Foreign Demand

The future economic environment of U.S. agriculture will be fundamentally different than in the past, in part because export markets have become more important than domestic markets as a basis for growth. The export markets are likely to be volatile and there may be extended periods during which they grow too slowly to absorb growth in U.S. production. Domestic food markets will grow, but more predictably and at a relatively slower rate. Traditional export markets, such as for grain and oil crops, do not support growth of that portion of the agribusiness sector that processes and markets domestic food products.

This study now turns to an analysis of the supply response of U.S. agriculture to alternative world food situations, and to the implications for farmers, consumers, farm input suppliers, the postharvest marketing sector, and foreign trading partners. The impacts of exports on agriculture are examined first. Then the analysis turns to resource availability and allocation.

Export markets compete with domestic markets for food. Therefore, if exports are to increase without reducing domestic use per capita, then either the quantity of resources used in agriculture must increase or the productivity of resources already in use must improve. These relationships are captured in the following equation:

$$\text{domestic food per capita} = \frac{(\text{resources used X yield}) - \text{exports}}{\text{population}}$$

The equation provides useful insights into the world food problem and it points to the kinds of data required to describe the present situation and to project the future. It relates factors affecting the role of U.S. farmers in meeting world food needs to the prospects for gaining access to additional land, water, energy, and technology.

However, although the relation is widely used, it oversimplifies. It fails to recognize the interaction of structural change with productivity. Second, if the analysis is done at a high level of aggregation, a pessimistic conclusion always follows: if yield does not increase faster than a specified rate, then resource use limits growth. This same pessimistic conclusion can be stated differently: if the use of resources does not expand to a specified level then technology limits growth.

The oversimplifcation can be removed by disaggregating the variables in the equation, by introducing other explanatory variables, and by allowing for substitutions in production and consumption (*150*). Disaggregation can be by kind of resource, regional location of production, type of farm, and type of commodity. Additional explanatory variables include institutional considerations such as type of farm organization, tenure, market structure, and government programs. The additional equations required to describe the additional variables include those that analyze substitutions in consumption and in production among resources, regions, and commodities that are induced when a bottleneck occurs with respect to a particular resource used in a particular region for a particular commodity. When analysis penetrates beneath the aggregates, a more optimistic conclusion may be reached about the ability of U.S. agriculture to meet expanding domestic and foreign demand because the analysis then allows for the flexibility and resilience of agriculture in response to change. The disaggregation can be and often is done intuitively with good results. However, to do it systematically requires an explicit and detailed economic model. The modeling approach was used in this report.

The considerable opportunity for substitution and adaptation is evidenced by past trends. Less labor is used in agriculture in combination with more purchased inputs on about the same amount of land to increase farm output (*269*). The effects of exports on agriculture, using a model that permits flexible substitutions, were examined by Meister, Chen, and Heady, whose conclusion is a compact summary of what detailed and explicit models can reveal:

> "The main impact of higher exports is the increase in the general price level. Higher prices have the apparent effect of reducing per capita consumption of food. . . United States agriculture can produce these high exports. . . Higher commodity prices and land rents conform with greater income to the farmers but higher food costs for consumers. . . Substantial interregional shifts occur in land use and cropping and in livestock production patterns" (*159*, page 72).

Two relatively complex models of U.S. agriculture, involving more than 300 equations each, were relied on in this report to evaluate the impacts of alternative world food situations. One captures the structure of supply and demand in the markets for U.S. farm commodities over time. This time-series ERS model is called the Food and Agriculture Policy Simulator (FAPSIM) (*216*). The other is a regional mathematical programming model that solves for the efficient allocation of land, labor, and other farm inputs among agricultural commodities at a given time. This cross-sectional ERS model is called United States Mathematical Programming Model (USMP) (*111, 112, 113*).

Adjustment to Alternative Export Trends

Three questions were posed for the time-series model concerning longrun trends:

- What happens to U.S. farm prices, volume of production, and income if export markets grow relatively rapidly in coming years, as would be expected were the world food situation to become relatively tight?

- What happens to U.S. farm prices, volume of production, and income if export markets grow relatively slowly in coming years, as would be expected were world food supplies to become relatively plentiful?

- What hypothetical rate of growth in export markets approximates the central scenario wherein real food prices are about constant over time, and how does this compare with current prospects for actual growth in the export markets for U.S. farm products?

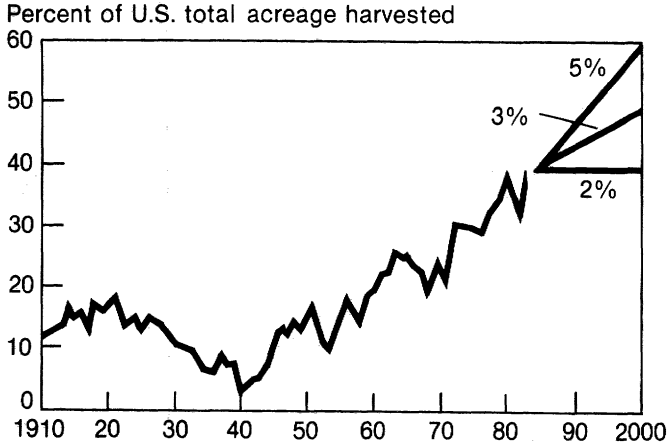
A simulation of alternative futures, based on the structure of U.S. commodity markets for major crop and livestock products over the last decade or two, helped to answer these questions. Alternative time paths from 1982 to the year 2000 were examined for production and use of major commodities, for prices, and for farm income under alternative assumptions about the market for U.S. crop exports. The alternative scenarios assumed different growth rates in exports: 2 percent per year, 3 percent, and so on. Seven crops were included in the analysis: wheat, corn, sorghum, barley, oats, soybeans, and cotton. Yields per acre increased a little over 1 percent per year using yield trend equations. Seven livestock products, consumed domestically but not considered for export, were also included: beef, pork, young chicken, other chicken, turkey, eggs, and milk.

Scenario 1—Average Growth. If export growth averages 3 percent per year, the proportion of acreage harvested for export by 2000 will rise to 50 percent (fig. 3). Forty percent of harvested acreage is for export now, up from 20 percent a decade ago. This and the projected 1-percent annual growth in domestic markets will about absorb prospective increases in domestic capacity. U.S. exports are projected to grow slightly below the 3-percent rate during the coming decade, although year-to-year variations are expected above and below that level. Considering worldwide trends toward increased production, the U.S. share of world production is likely to decrease, as is the U.S. share of world trade. However, under the 3-percent scenario, the United States will continue to be the major exporter of farm products during coming decades.

Growth in exports of 3 percent per year will about absorb the potential growth in production, given the expected growth in domestic markets. Production would expand to satisfy both domestic and foreign demands with little change in consumers' real food prices. This suggests that domestic agriculture must become increasingly dependent on foreign markets if growth is to be accompanied by a balance between the interests of domestic consumers and the interests of farmers. Price and income levels would require little or no support from present farm programs were the programs to be continued. This scenario implies less than a 10-percent increase in cropland use over the

Figure 3

Acreage Harvested for Export Since 1910, with Projections to 2000



next two decades, with most of the added acreage for soybeans. (The supply of cropland to meet these needs is discussed in the section "Implications for Resource Use in U.S. Agriculture.") Consumers would eat more beef, pork, and poultry, and more soybean, corn, and barley products than in 1982, but the domestic food market would be smaller for other grain and livestock products.

Scenario 2—Slow Growth. If exports rise only 2 percent per year for a period of years, the analysis shows that the forthcoming food supply would be large relative to demand. We would then find ourselves with food surpluses, downward pressure on prices received by farmers, and deep concern for moving excess resources out of a depressed agriculture. Farmers would produce less wheat, corn, soybeans, and cotton, and about the same amount of livestock products compared with average growth (scenario 1). Real prices received by farmers would decline for all commodities. Farm income and land values would decline relative to what they would have been with stronger export markets. If advanced technology continues to be adopted, then many resources now used in agriculture might not be required. For example, less cropland will be used in 2000 than in 1982 if exports expand no faster than 2 percent per year. There might be incentives to expand exports and pressures to continue programs that support farm income. If present farm programs were to continue, deficiency payments based on the gaps between market prices and target prices would constitute a large share of farm income. Domestic consumers, however, would benefit from plentiful food supplies and lower real prices; they would spend a smaller share of disposable income for more food, and the volume handled by the marketing sector would increase.

Scenario 3—Fast Growth. If, instead, export markets rise at an annual rate of 4-5 percent per year, we would find ourselves in a situation of scarce and costly food supplies with deep concerns for where to find the resources to expand production. Demand would be large relative to supply. There would be little or no incentive to seek further acceleration in demand. Real food prices would increase. Livestock product consumption would probably decline but dairy product consumption would be sustained and more wheat products would be consumed. Consumers would pay a larger share of income for a smaller quantity of food than under the 3-percent scenario, and the volume of food products handled by agribusiness would decline. Consumer groups and the marketing sector would have the incentive to limit price increases and to divert more of the farm output into domestic markets. Such actions were suggested during the seventies when the rise in prices received by farmers took part of the blame for domestic inflation.

Farmers and farm input suppliers benefit from scarce world food supplies and rapid export expansion. Crop farmers would receive more benefits from expanding exports (of grains and oilseed crops) than do livestock farmers, and the larger and more efficient commercial farmers receive more benefits from programs that protect agriculture than smaller commercial farmers. Farm income will increase sufficiently under the 4- and 5-percent scenarios so that deficiency payments, if present farm programs are continued, will not be required. More resources would be needed and higher prices would be paid for them. Acreage planted would increase by about 20 percent above the 1982 level under the 5-percent scenario and land values would rise. The potential to convert this much land to cropping uses is high according to the 1982 National Resource Inventory. Pressures against natural resources would reduce yields slightly relative to the 3-percent scenario despite the inducement of higher prices received to increase yields. The proportion of acreage harvested for export would rise to around two-thirds of harvested acreage by 2000 and agriculture would be very dependent on foreign markets.

U.S. farmers experienced pressures not unlike the fast growth scenario during the seventies and the slow growth scenario during the eighties. In the long run, growth of export markets is expected to average within the range of 2 to 5 percent, and if it does the agricultural system has enough flexibility to adapt to a wide range of alternative economic situations. However, the accompanying changes in relative prices will induce redistributions of income among consumers, the marketing sector, farmers, resource suppliers, and U.S. trading partners. Simulations outside the range, for example at 1 percent or 6 percent, indicated that the stress on agriculture would be great and structural changes would be induced beyond the powers of the model to examine.

The main conclusions reached with the aid of the simulation over time concerning the U.S. supply response to alternative world food situations are:

- The domestic market does not support a growing farm sector. The growth and economic health of U.S. agriculture depends increasingly on the growth and reliability of export markets.

- Export growth sufficient to absorb increases in output without depressing prices requires that export markets grow close to 3 percent per year. With such growth, the acreage harvested for export would rise to 50 percent by the end of this century, making U.S. agriculture even more dependent on world markets.

- Current prospects are that U.S. crop exports will grow slightly under 3 percent per year in the coming decade and that the capacity to produce crops for export will grow by slightly over 3 percent. Therefore, agriculture has the capacity to meet expected demands even at moderately decreasing real prices received.

- Growth of less than 2 percent per year in export markets is unlikely for the long term. Were growth to fall much below the trend of 3 percent, we could expect plentiful food supplies for domestic consumers but, in the absence of farm income and price support programs, depressed farm incomes, capital losses, and shifting of resources out of agriculture in search of better economic opportunities in the nonfarm sector.

- Growth of more than 5 percent per year in export markets is unlikely for the long term. Were growth to rise much above the trend of 3 percent, we could expect higher real food costs to domestic consumers and reduced consumption of livestock products relative to crop products. Livestock growers would sell fewer products at higher prices; crop growers would sell more at higher prices. Farm income would be high enough to eliminate payments and supports under present farm programs (except perhaps for dairy). Capital gains would accrue to landowners.

- Resource availabilities and prospective advances in technology seem adequate to support domestic markets that grow in line with past trends and export markets that grow between 2 and 5 percent per year. If exports grow less than that, the agricultural sector could again become distressed, with low prices and incomes. If export markets grow more than that, various social, institutional, structural, and distributional problems could beset agriculture long before natural resource availability becomes limiting. Considerations are likely to arise such as how to maintain balance between consumer and farmer interests, between livestock and crop growers, and between landowners and land users as relative prices change for commodities and resources.

Reallocation of Scarce Resources

Additional questions were posed for the cross-sectional model concerning the allocation of agricultural resources among commodities and regions under alternative export situations:

- What regional adjustments are likely in commodities and inputs in response to a change in crop exports?

- What regional adjustments are likely in commodities and inputs in response to a change in the volatility of export prices?

- What might happen to the supply of commodities for foreign and domestic use when more resources are made available to agriculture, or when technology advances?

The second and third questions are treated in the subsequent section on "Implications for Resource Use in U.S. Agriculture."

The cross-sectional analysis of the first question both complemented and supplemented the time-series analysis and is discussed here. This part of the analysis is based on simulations of four alternatives to the present situation, with 30, 60, and 90 percent more exports than now and with 30 percent less, using present technology. The time path for adjusting to the alternative conditions was not examined. One can imagine it would take a decade or two for farmers actually to make the indicated adjustments.

The cross-sectional and the time series simulations describe the demand for commodities in about the same way. The commodities included in the two analyses are about the same. The cross-sectional analysis includes rice and disaggregates some of the livestock products. For example, it separates beef into fed beef, nonfed beef, veal, and cull cows. However, on the supply side, the cross-sectional analysis is based on a fundamentally different kind of analytical framework than the time series analysis; it uses different data and logic. For example, it recognizes more wide-ranging adjustments in resource use in response to changing relative prices than does the time series analysis. Consequently, while the two approaches overlap in some respects, they provide different perspectives for dealing with the questions posed. Only the time-series results have been discussed so far. The following paragraphs present the cross-sectional results and include comparisons with the time-series results.

Both simulations indicate that a more limited world food situation with a higher export level will improve farmer incomes, reduce domestic consumer welfare, induce shifts toward relatively less livestock products in domestic diets, and create capital gains for owners of farm assets. And both indicate that U.S. agriculture has the potential to meet the market demands likely to be placed on it in coming decades.

An increase in exports of cash crops will improve farm income, but the gains will be mostly for crop enterprises. Livestock enterprises will face higher feed costs, which will reduce livestock production and, despite higher prices received, income. Each 10-percent increase in crop exports would induce about a 2-percent increase in cropland, 2-percent increase in hired labor, and 0.2-percent decrease in pastureland use after sufficient time had elapsed for all the reallocation adjustments to be made. Cropland rental and wage rates would increase. The use of most purchased farm inputs would increase as exports increased, but fewer inputs would be required in the declining livestock sector. For example, the use of pastureland, grazing land, and veterinary services would decline. Expanding crop exports would lead to increasing demand for farm inputs resulting in higher prices paid by farmers and in improved income for the owners of farm inputs.

The cross-sectional simulation is in agreement with the time series in showing that U.S. agriculture has the ability to respond to substantial growth in exports. Assuming no change from present technology, a doubling of crop exports would require a 20-percent increase in cropland after all allocative adjustments are made. This is well within the availability of land with a high potential for conversion. If an allowance were made for technological advance, then less additional land would be required.

The supply response to expanding exports is accomplished, according to the simulations, mostly by increases in production, although there are some reductions in domestic use and storage. The supply response is more elastic (more responsive to price changes) in the cross-sectional analysis than in the time series. This is an example of how the equations in an economic model can predetermine whether an analysis will arrive at an optimistic or a pessimistic conclusion. The cross-sectional simulation incorporates considerable opportunity for resource and commodity substitution of the kind expected as agriculture approaches longrun general equilibrium. It therefore indicates relatively more production and less price response to a change in exports. The time-series simulation indicates relatively more price and less production response. Price increases associated with expansions of exports by 30-60 percent above the base level induce more production of cash crops according to the cross-sectional study (an elastic supply response). The supply response is moderately inelastic for further export increases: that is, production cannot rise much more, even when encouraged by higher prices. For the time-series study, however, the supply of cash crops is relatively inelastic throughout the entire range examined, so increased demand raises prices more than production.

Prices would increase for both crops and livestock as crop exports increase. Higher prices for feed grain would limit the use of feed for livestock, so a reduced quantity of livestock products would be supplied to consumers at higher prices. The supply of corn is more elastic than the supplies of soybeans, oats, and barley, so the price of corn would increase less than in proportion to prices for the other feed grains. Corn would replace some of the sorghum, oats, and barley used to feed livestock.

Consumer welfare changes are similar in both simulations because both use essentially the same domestic demand structure. As exports of cash crops expand, consumers pay higher prices and a larger percentage of income for less food, particularly less livestock products.

The supply response of U.S. agriculture displays important regional variations. Figure 4 shows relative changes in net income (gross income less variable cost) for 10 multistate regions in response to a 30-percent increase in the exports of all crops. The relative gains would be greatest in the Northern Plains and Mountain regions. The figure shows changes in net income, but the cross-sectional model includes additional detail. The Northern Plains region would lose more of its value of livestock production than other regions, but this would be more than offset by gains from increased production of wheat and corn. The Mountain region would produce more corn both for export and as feed for cattle, thus realizing gains in both crops and livestock receipts. Growth in income would be lowest in the Pacific region where strong gains in crops would be about offset by losses in the value of production of livestock. The Northeast region would lose only slightly in livestock receipts but would be the least able region to profit from the expansion in crop exports.

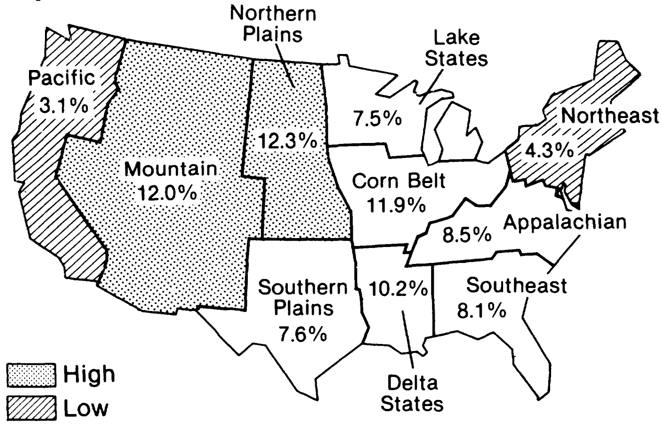
Distributional Consequences

The flexibility of U.S. agriculture to adjust to a wide range of alternative export situations shifts the concern from the feasibility of producing enough food to the prospect for substantial redistributions of income as agriculture adjusts to changes in its export markets. Alternative world food situations have important implications for the distribution of benefits and losses among consumers, the marketing sector, farmers, resource suppliers, and U.S. trading partners.

Consider the distributional implications of another world shortfall of feed grains, for example, such as was experienced during the seventies. Many variables would be affected; while each individual change caused by a shortfall of feed grains is plausible enough once it has been noted, the collection of all changes as the economic forces multiply through the economy form a complex pattern, which can be traced by the cross-sectional model. The consequences of an increase in exports favor some groups and slight others. As the world price of a relatively scarce commodity increases, the United States, as a residual supplier, would increase its exports. This would draw down

Figure 4

Regional Change in Net Farm Income in Response to a 30-Percent Increase in Crop Exports



stocks, reduce the domestic supply of grain, and increase the domestic price. More resources would then be attracted to produce the scarce commodity. Part of the added resources would come from reduced inputs into other commodities, but aggregate resource use would increase. Derived demands for land, labor, and purchased farm inputs would increase. This would be accompanied by more intensive land use, additional problems with soil erosion, and increased use of farming practices harmful to environmental quality. Factors prices would rise. More land would be used at higher rents, more labor at higher wages, and more purchased farm inputs at higher prices paid by farmers. Costs of production would increase for all commodities as a consequence of the higher prices paid. Diminishing returns would add to the unit costs of producing more of the relatively scarce commodity.

Resources would be drawn from the production of other commodities. Reduced supplies of other commodities would in turn cause their prices to increase. Consequently, prices received by farmers would be higher than they would otherwise be for all commodities, not just for the commodity that was relatively scarce. With inelastic domestic demand, and an expanding export market for grain, prices received would rise more than prices paid and farmers' profits would increase.

Consumers would pay more and get less. There would be a reduced flow of food through domestic marketing channels. This need not offset the effect of higher retail prices on marketing profits. But, because most postharvest value added is for domestic rather than export markets, the reduced flow would idle some plant and equipment in the food and kindred products industry, which, in turn, would cause unemployment and increase unit costs. Some industries involved directly with exports of the scarce commodity, however, would gain—transportation facilities, for example. Exports of other commodities than the one initially in scarce supply would decline in response to their increase in price.

The expansion in export demand for one commodity results in reduced exports of others and higher prices for all. The changes have an adverse effect on domestic consumers, the domestic marketing sector, and importers of other commodities. However, they benefit farmers, resource owners, and suppliers of purchased farm inputs.

Now turn the example around. If, as was experienced during the eighties, foreign and domestic markets do not increase rapidly enough to absorb potential increases in U.S. agricultural production at present real food prices, prices will tend to weaken for all commodities. This would hurt farmers by reducing income and limiting their incentive to invest. If the weakness is in world grain prices, livestock producers could profit from lower feed costs. Moderation in the demand for farm inputs would reduce the value of land, labor, and capital. Input suppliers would suffer capital losses and reduced incomes while consumers and trading partners benefit from lower prices. The domestic marketing sector would benefit from an increased volume of processing, transportation, and marketing services.

As export markets become an increasingly major segment of the total market for U.S. farm products, U.S. policies may need to focus not only on the steady growth in the size of the markets but also on the substantial potential for changes and reversals in world food trade to redistribute income.

Impacts of Volatile World Prices

Volatility from foreign sources has affected agriculture throughout this century. The major exception for U.S. farmers was during the fifties and sixties, when massive U.S. government intervention stabilized domestic farm prices above world prices and therefore above prices that would have existed without commodity programs. Price support programs and accumulated commodity surpluses kept prices within narrow ranges. During the seventies, domestic U.S. policies allowed world price fluctuations to affect domestic prices more directly. Since 1972, the world food balance has oscillated between excess supply and excess demand. Reduced world grain stocks, bad weather in some parts of the world, and policy changes in major importing and exporting nations resulted in highly volatile grain prices during the seventies. Developed and underdeveloped countries alike discovered their potential vulnerability to short-run changes in food prices, and many countries devised trading strategies to insulate and protect themselves.

Variations in wheat and corn prices are shown in table 1. The table shows two periods of relative price stability: before World War I and after World War II. While the variation of the seventies was not high compared with that before World War II, it was high compared with 1951-71 for both wheat and corn. Comparison of pre-1950, open-pollinated corn prices with subsequent hybrid corn prices may be misleading, but both the corn and wheat price series tell approximately the same story.

Price variation in table 1 reflects changes in domestic production and consumption in addition to influences of world prices. Even so, changes in domestic prices received by farmers were correlated with world price fluctuations when domestic programs kept prices close to world levels, and prices were relatively stable when programs supported prices within a narrow range above world levels. Prospects for transmitting a continued high degree of price fluctuation from world markets to domestic farmers, particularly for crop products, has implications for U.S. farmers' decisions on production and income.

World grain stocks in 1970 were about 15 percent of annual use compared with 20 percent in the early sixties, increasing the sensitivity of prices of changes in production. World grain production fell by about 3 percent in 1972, partly because of adverse weather in some parts of the world, including the

USSR, and partly because of continued production controls in the United States. In a major policy shift, the Soviet Union entered the world market in mid-1972 to purchase 23 million metric tons of grain—about 60 percent of it from the United States. World grain stocks fell to 12 percent of annual use by the end of 1972. While conditions stabilized to some extent in 1973, a 1974 drought reduced U.S. corn production and contributed to a 4-percent decline in world grain production.

Price shocks were extreme. The rapid transition from surplus stocks to shortages caused grain and soybean prices to reach record high levels. Those high prices benefited crop producers but proved unprofitable to the livestock sector. Sharply rising food prices and unrelated political considerations led the United States to embargo certain agricultural exports, straining long-standing trade relationships.

Many farmers, expecting permanently higher prices and income, were encouraged to make large capital investments to expand production. The expansions usually required more debt. There was a steep downturn in prices in 1976 and 1977 as production improved and stocks increased. Although incomes increased in 1978 and 1979, they fell 30 percent in 1980 as inflation-induced increases in expenses cut into gross incomes. Increased production and slackening export demands further cut farm prices and incomes in 1981 and 1982, and increased wheat and corn stocks.

Floating exchange rates, adopted by world financial organizations in 1972, contributed another source of instability that had not been present during the fifties and sixties. Yield variation due to natural causes increased in the seventies in some regions as grain production expanded onto arid land. And more of the previously existing variation was transmitted to world markets because of protective trade policies adopted by both grain exporting and importing countries. Carryover stocks, held primarily by the United States, played a major role in the price swings. The depletion of these stocks by the mid-seventies magnified the destabilizing effects of world production shortfalls. By the end of the decade, however, U.S. grain stocks were again relatively large and helped stabilize the world grain market. In addition, farmers and private traders were turning more to futures markets, options, and other financial strategies to share the risk of volatile grain prices.

Now that the food crisis of the seventies is over, each major price change can be seen, in hindsight, as a special case that need not be repeated. Even so, world price and trade fluctuations continue and policies have not yet been adopted by major food traders to stabilize world prices and trade in the event of another crisis. The potential for world food price volatility likely will continue and may even increase in coming decades. We are not likely to return to the relative stability of the fifties and sixties.

An important source of price volatility affecting U.S. farmers comes from overseas. Individual farmers can only adapt to these changes. However, price-stabilizing influences come from several sources. Natural buffers, such as increases and decreases in the size of the livestock sector, can absorb variations in grain production. Farmers and traders can protect their positions using futures or options markets. Institutional buffers, such as private grain speculation and stabilization policies by governments, can absorb shocks. Consumers, in response to price signals, can reduce consumption in times of shortage, consume more grain relative to livestock products, and reduce waste. Regional shortages can be shared by increased trade. And the shortages, themselves, subsequently can induce increased production. If all of these are insufficient, and if prices received by U.S. farmers continue to reflect a high degree of price volatility, then the resulting adverse effects on farmers and consumers imply a need for the U.S. government to insulate U.S. farmers from the price volatility.

It is not clear if world weather patterns are becoming more volatile. The geographic location of variation may shift, but

Table 1—Instability of wheat and corn prices, 1900-1982

Period	Wheat			Corn		
	Average price	Standard deviation	Coefficient of variation	Average price	Standard deviation	Coefficient of variation
	Dol. per bushel			*Dol. per bushel*		
1900-15	0.82	0.14	17	0.54	0.13	23
1916-38	1.12	.49	44	.80	.34	42
1939-50	1.41	.58	41	1.12	.47	42
1951-71	1.73	.31	18	1.23	.19	15
1972-82	3.13	.91	29	2.30	.56	25

Source: Tom Miller et al. (*166*).

there is no evidence that aggregate world food production is more or less uncertain than it was. Changes in policies influence the way regional variations in local production affect the world price. U.S. production tends to be more stable than world production as a whole. The increasing reliance of U.S. agriculture on exports makes prices received by farmers more sensitive to changes in the import and export policies of others. It was prices, not world production, that became more volatile during the seventies than during the fifties and sixties.

Farm specialization and increased international trade make many countries more dependent on world markets. This increases the volume of world trade relative to production (*95, 253, 293*). The increases in volume of trade can be accompanied by relatively larger fluctuations; for example, to maintain and upgrade diets during periods of adverse weather requires a temporary increase in imports. Policies that stabilize the food supply for one country make the market more unstable for other countries. A country may achieve stability for itself by maintaining or increasing its purchases of food in times of shortage and dumping the excess in times of surplus. Several countries have set up protective trade barriers that stabilize their internal agriculture but destabilize markets in the rest of the world. The USSR, EEC, Argentina, and Australia have followed policies in recent years that transmitted domestic variations into world markets (*20*). Government intervention in world markets can be a major source of market volatility.

As world prices become volatile, the tendency is for less developed countries to become cautious and use restrictive trade practices. These actions further exacerbate volatility for other countries. At the same time, the degree to which developed economies share the burden of adjustment to fluctuations through free trade declines as their share of world consumption declines.

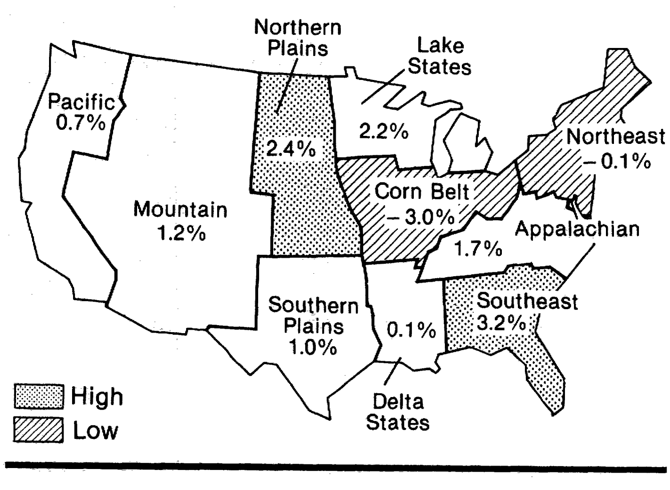
Volatile prices in world food markets, when transmitted into the U.S. economy, affect decisions made by U.S. farmers. Farmers who are risk averse treat increasing uncertainty like an increase in the cost of production, or like a decrease in the price received for a product. They cope with uncertainty by diversification, flexibility, reluctance to borrow and invest, off-farm employment, and other actions that may reduce production and efficiency and may limit investment. Price uncertainty and income variability affect the financial position and vitality of individual farm businesses as well as farmers' ability to follow soil conservation practices. Increased variation in world food prices reduces the U.S. supply of cash crops by risk-averse farmers (*111, 113, 165, 166*). Supply also becomes more inelastic as the degree of volatility increases. The reduced willingness to supply crops at a given price leads to higher prices received by farmers. This encourages more output but not enough to offset the reduction due to uncertainty. The higher prices lead to reduced quantities of crop products used in food, feed, and export markets. Income to crop enterprises improves, but the reduced demands for farm resources reduces the income to resource suppliers. Higher feed costs reduce income to the livestock enterprise.

Net income (gross income less variable costs) increases slightly for agriculture as foreign markets become more uncertain, but the regional impacts vary (fig. 5). With a doubling of the standard deviation of prices received for export products, income would increase as total U.S. cropland declined (after all adjustments were completed, according to the cross-sectional analysis) as farmers protected themselves from the increased risk; however, crop acreage in some regions would increase. The Southeast would realize the largest relative income gain because expansion in acreage harvested would tend to increase output there. The Corn Belt would realize the largest relative loss because a decrease in acreage harvested would reduce output by more than enough to offset the higher price.

An increase in price volatility would reduce the supply of food and increase the concentration of farm production (*166*). The proportion of larger farms would increase as would the proportion of part-time farms with off-farm income. There would be an increase in the income of farmers who produce crops for export. But the total acreage in crops would decline because some crop farmers would have smaller enterprises, and there would be fewer farmers. Livestock farmers would be hurt by higher feed costs. Beyond the farm gate, increasing variability of farm prices would add to the costs of postharvest processing and handling and would increase consumer prices. Suppliers of inputs to farmers would experience reduced demands. Domestic users and trading partners pay higher prices to consume less when international food markets become more changeable.

Figure 5

Regional Change in Net Farm Income in Response to a Twofold Increase in Uncertainty



Many public policies affect price and income stability: international trade policies, price support programs, grain reserve programs, credit programs, market information and outlook activities, and Federal income tax laws. As the major grain exporter, and with its domestic markets open to world price influences, the United States is the main shock absorber in world grain markets. Few other countries operate grain storage programs capable of reducing world price variability. Grain carryover stock management has moderated the effects of instability, but sometimes it augmented the shocks as well. Countries with no stocks above the level needed for normal use have added to the instability of world food markets during temporary periods of shortage or abundance. U.S. stockholding, large as it is, is sometimes insufficient to bring a noticeable degree of stability to world markets.

If U.S. agriculture produced only for domestic markets, then domestic stabilization policies to protect farmers against domestic sources of instability could work as they did in the past. But U.S. farmers now produce increasingly for world markets. This raises an interest in whether domestic policies can protect farmers from a buffeting by world price instability.

Carryover stocks could be involved if stability were desired. Management of the stocks would reflect judgments, such as described by Eaton, about competing public objectives (*53*). Government-managed stocks can protect farmers from low prices and consumers from high prices as markets become more volatile. However, all policies have side effects. For example, price stabilization under a stock management program can induce a shift in the supply function for agriculture which raises output and reduces prices received by farmers.

Consider a price stabilization program that acquires stocks at a specified support level and disposes of them at a higher, specified release level. Such a policy appears to be able to protect farmers from extremely low prices and consumers from extremely high prices. Eventually, however, a run of short crops is sure to come. Stocks would go to zero and there would no longer be any mechanism for keeping a lid on prices. Or a run of bumper crops would come. Then stocks would become unacceptably high and there would no longer be any mechanism, short of supply control, for keeping a floor under prices. This view of stockpiling has been modeled by Plato and Gordon (*193, 194*). Any program that stabilizes prices through stock management runs the risk eventually of either depleted stocks or unacceptably burdensome stocks. The question becomes: what situations and what management strategies increase the probability of maintaining prices within prescribed bounds?

An increasingly tight world food situation increases the probability of holding either too much or too little stocks for effective stabilization. The reason for that is that a tight world food situation induces agriculture to produce at a level close to capacity, making the supply more inelastic. The more inelastic the supply of farm products, the less farmers can adjust to price changes, and the more the burden of adjustment will fall upon the stabilization program. An increasingly volatile world food market also increases the probability of holding either too much or too little stocks because the greater variance increases the likelihood of a run of high prices or of low prices. Once either event is realized, the probability of subsequent occurrences increases. For example, once stocks have gone to zero, it is more likely that the market price will again rise above the release price before the depleted storage stocks can be replenished.

If farmer interest groups press for high support and release prices, and consumer groups for low ones, the resulting compromise could be a fairly narrow range between the support and release prices. A narrow range increases the probability of experiencing prices above or below the range, and increases the expected annual cost of operating the programs. In addition, a narrow range drives private storage operations and speculators out of the market, so the government finds itself taking over most of the country's storage function and taking over a larger role in determining price. To keep private storage operations in business, to give futures and options markets an opportunity for risk sharing, to keep the cost of operating the program low, and to keep the probability of either kind of program failure low, the support level may have to be lower than many farmers would like and the release level higher than many consumers would like. Increasing the support price relative to the expected price increases the probability of accumulating too much. If supports raise the domestic price above the world price, U.S. exports would tend to lose their competitiveness in world markets and other countries could expand production to meet the world demand; the U.S. share of world food trade could shrink. Similarly, reducing the release price relative to the expected price increases the probability of depleting stocks altogether.

Continued world grain market volatility is expected in coming decades. The structure of world grain trade is increasingly dominated by state trading organizations, bilateral agreements, and other trade restrictions that limit supply and demand adjustments in much of the world. If more markets become insulated from world prices, an increasing adjustment burden will have to be meet by those not insulated, especially the domestic U.S. market.

Implications for Resource Use in U.S. Agriculture

Growth in the production potential of U.S. agriculture depends on the availability of resources to farmers and on the productivity of those resources. It is affected by agriculture's flexibility in reallocating resources and shifting regional location to accommodate a changing economic environment and changing economic incentives. And, production is affected by institutional arrangements such as regulations affecting resource use, tax laws, and farm programs. Factors determining growth in agricultural production are examined in the following sections.

The analysis that follows supports the view that "the productive capacity for both agricultural and forestry products will be adequate to readily sustain increases in output to meet projected global demand for U.S. products to 2000" (*58*). U.S. agriculture is not likely to increase appreciably its use of natural resources in coming decades, although close attention will be required to maintain and conserve what is now in use. Some additional cropland is available to be developed and it may be needed. The annual use of irrigation water on arid lands, which was a major source of agricultural growth during the past three decades, is not expected to increase very much during the next three, although irrigation increases are expected in humid areas. The exodus of labor from farm to nonfarm jobs is apparently over. Labor retention will likely increase as export markets expand, yet the supply of agricultural labor should be adequate. Growth in farm production will depend heavily, as it has during the past three decades, on increased use of purchased farm inputs. These are expected to be available from the nonfarm sector at prices about in line with changes in the real prices of producer goods and services. Energy prices, however, could again be a source of increasing real cost to U.S. agriculture before the close of the century. A number of technological advances, if developed and adopted, are expected to improve the productivity of resources used in agriculture.

For these reasons, which are elaborated below, U.S. agriculture is expected to have the ability to meet the domestic and foreign market demands likely to be placed on it in coming decades.

Land

To obtain sufficient growth in production to meet prospective market demands for U.S. farm products in coming decades, the natural resource base used by farmers will need to be maintained or moderately increased. Maintaining the present natural resource base will require active continuation of conservation and development programs, else the base could diminish and needed capacity would not be available. While the aggregate level of the natural resource base need not become limiting, natural resource problems of a local or regional nature can be anticipated such as reduced level of irrigation water in one county, or heavy losses to erosion in another. In addition, resource development will be required to offset shifts of resources from agriculture to nonfarm uses.

About one-fifth of the U.S. land area is cropland and another one-fourth is pasture and range. Of these, cropland is the more useful indicator of farm capacity because a greater share of the value of farm output depends on crops either as final farm products or as inputs to livestock enterprises.

The 1982 National Resource Inventories (NRI) estimated that there were 421.4 million acres of cropland in the United States compared with 413.3 million in 1977. An additional 35.3 million acres (8.3 percent of the total) is considered to have a high potential of conversion to cropland, about the same as the 36.2 million acres so considered in 1977. An additional 117 million acres (27.9 percent of the total) is considered to have a medium potential for conversion compared with 90.8 million in 1977. Counting land identified with low potential for conversion plus other private and federally held land that is croppable, it is feasible that U.S. cropland could more than double. But to do so would not be the most efficient way to expand output. There are other uses for the potentially available land than food production, and there are many opportunities for using the present land base more intensively. Conversion is not without costs and conversion of much of this land may not prove cost effective. Much of the feasibly convertible cropland has problems with seasonal high water tables, high-density forest, stone or rock outcrops, low fertility, lack of dependable water, high erosion, flooding, or is located on small or isolated tracts.

Cropland may be increased by 17 percent above the 413.3 million acres inventoried in 1977 before conversion difficulties and accompanying high conversion costs are encountered (*138*). Applying Lee's estimate to the 1982 inventory of 421.4 million acres suggests that some 70 million acres of cropland might be added on a cost-effective basis.

The potential to convert other lands into cropland has always been available to U.S. agriculture. During the past half century there was insufficient economic incentive to use this potential. Cropland harvested was 349 million acres in 1982, close to the maximum ever harvested of 361 million acres in 1932. The growth of U.S. food production was governed by growth in the size of markets and not by natural resource availability. Production grew by more intensive use of the same land area: higher yielding varieties, supplemental irrigation, double cropping, and other management practices.

More intensive land use may be a more economical means of meeting growing demands than developing more land (*25*). Boxley presents double cropping, a practice that is not widespread but shows signs of expanding, as an example. Fourteen million acres were double cropped during 1982, up from 4 million in 1969. In 1983, when cropland harvested was reduced by 56 million acres, the double-cropped acreage was reduced by only 2 million acres. An increasingly common practice is to plant soybeans following another crop such as wheat. Twenty-two States report at least some double cropping of soybeans. In Georgia, South Carolina, Florida, and Alabama, nearly half of the soybeans were double cropped in 1982.

Use of double cropping is related to: (1) adoption of faster maturing plant varieties; (2) improvements in machinery capacity and efficiency plus use of artificial crop drying to permit earlier harvest and faster seedbed preparation for a second crop; (3) expanded use of herbicides and pesticides; (4) less tillage (minimum- or no-till) which permits immediate reseeding following harvest; and (5) favorable soil moisture conditions during the relatively narrow period available for planting soybeans following a small grain crop (*25*). Unfavorable moisture conditions during this period is probably a major explanation for the year-to-year variation in the proportion of double-cropped soybeans in some States. Supplemental irrigation to assure quick seed germination may be important. Double cropping requires careful management, but there are no apparent physical constraints to further expansion of double cropping in the Southern States, or, with development of quicker maturing varieties, to double cropping in more northerly States. Double-cropping practices affect wheat and soybeans in a 1-year rotation and include corn in a 2-year rotation. These three crops are important in meeting prospective export demands.

During the past 50 years, agricultural production was not limited by a lack of land. On the contrary, the problem was usually how much land to idle to limit price-depressing commodity surpluses. Perhaps the most influential factor affecting shortrun variation in the quantity of cropland was government supply management programs. In 1969, when cropland harvested was 75 million acres below the 1932 maximum, 58 million acres were diverted under government programs. Diverted acres are mostly held in conservation uses and pasture but farmers are sometimes permitted to grow crops on them like soybeans and sunflowers. Because of such programs, there is not a one-to-one correspondence between acres going into diversion and acres coming out of production. In 1983, 83 million acres were diverted under the payment-in-kind (PIK) program and harvested acreage was about 55 million acres below that of a year earlier. The United States found itself limiting food production while other countries were trying to produce more.

The stability in the aggregate level of cropland conceals considerable regional change, which can be explained not only by regional variation in potential cropland but also by regional variation in comparative advantage, impacts of Federal programs, and competition by the nonfarm sector for farm resources (*167*). Although the aggregate amount of cropland has changed little over the past half century, the amount used by an individual farmer, a county, or a region is not fixed. There are year-to-year changes in the amount of cropland that is double cropped, not harvested because of crop failure, held in summer fallow, left idle, or used for pasture and hay. Some land that had been idle for several years is again used to grow crops. Some cropland is converted to higher-value uses such as residential or industrial, while some is converted to pasture or forest. Some pasture land has high potential for conversion to cropland. A relatively small amount of forestland has potential as cropland. The social cost of converting other land into cropland includes not only the actual cost of conversion but also the opportunity cost of not keeping the land in its present use.

Each of the 10 multistate farm production regions of the 48 contiguous States reduced acreage during the sixties from a post-World-War-II high and then expanded again during the seventies, a period of rapidly expanding export markets (fig. 6). The Southeast, which had contracted more than other regions from its post-World-War-II high, expanded by 38 percent during this period. The Northeast expanded least, by 11 percent.

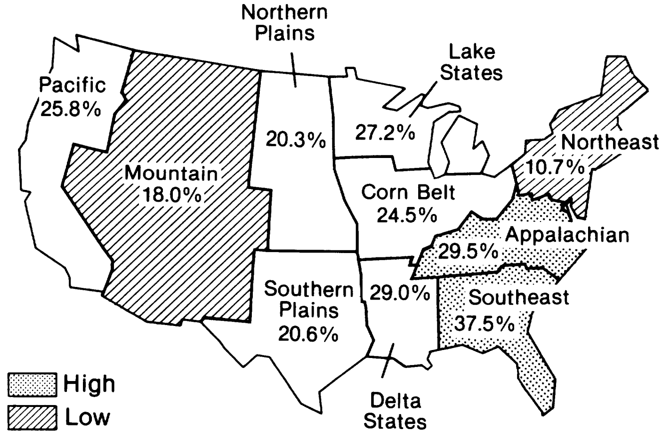
Five regions (Corn Belt, Lake States, Delta, Mountain, and Pacific) contracted moderately during the sixties and then expanded rapidly during the seventies. Their levels of cropland use rose, by the early eighties, above the previous highs. Four regions (Northeast, Appalachia, Southeast, and Southern Plains) contracted sharply during the sixties and subsequent expansions remained below their postwar highs. Cropland use in the Northern Plains returned to about its postwar high.

The Delta and Mountain regions were found by Lee to have a relatively large physical potential for additional cropland (*139*). The Northeast is unique in having not only sharp contractions in acreage in recent decades but also a relatively small potential for additional cropland. The Lake States, Corn Belt, Pacific, and Northern Plains showed strong growth during the past decades but the land available there for additional conversion is relatively moderate.

During 1949-69, when total cropland dropped by 9 percent, 785 counties had cropland gains and 2,332 had losses. During

Figure 6

Regional Change in Cropland Harvested, 1965-81



the seventies, when cropland increased by 3 percent (and cultivated land by 16 percent), 1,875 counties had cropland gains and 1,232 had losses (*109*). These changes indicate a considerable amount of turnover in land used for crops despite the stable total area of cropland. Increases in cropland from conversion and development are about offset by conversion of cropland to urban uses, abandonment, and other uses. Prime agricultural land may be converted to urban uses and replaced by land of lower quality. Some of the land abandoned in one year is returned to cropland use in another year. Cropland reclaimed by farmers after abandonment may be less productive than it once was. This recycling can be associated with an eventual deterioration in the quality of cropland; however, much former cropland is never returned to agricultural uses. The relation of the use of fragile lands to the ultimate capacity of U.S. agriculture is explored in the following section on "Soil Erosion and Export Growth."

Additional cropland is scarce for some regions and some commodities. However, there seems to be no obstacle to expanding the total quantity of cropland to 17 percent above the levels of the past half century at competitive costs of conversion if it is needed to meet expanding domestic and foreign markets. "Although thousands of acres of farmland are converted annually to other uses. . . we are in no danger of running out of farmland" (*263*). The time series and the cross-sectional analyses used in this study suggest that the cropland base is adequate to meet any market demands that may reasonably be expected during the next two or three decades. There are limits to the land base, but other problems discussed in this report would dominate before those limits are reached.

If U.S. exports were to increase by 90 percent above their present level, about 40 million more acres of cropland would be required, using current technology, after all resource and regional adjustments to the change were completed, according to the cross-sectional study. This is within the limits of potentially convertible cropland but it implies use of extremely fragile land for some crops in some regions. A similar (but more detailed) analysis by English, Alt, and Heady reached a similar conclusion (*55*). When that study allowed for future technology, such as agriculture might be expected to use during the next century, it found that exports could double during the next few decades and domestic plus export needs could be met using less cropland than now.

If U.S. exports increase by around 3 percent per year until 2000 (to a level 70 percent above the 1982 level), and if yields continue to increase in line with past trends, the time series analysis suggests that about 10 percent more cropland will be required. Export growth of around 2 percent per year (to a level 40 percent above the 1982 level) could be met with about the same amount of cropland now used. Present expectations are that actual exports will fall within this range of 2-3 percent average annual growth. If, instead, exports grow at an annual rate of 5 percent per year to 2000 (to a level of 140 percent above the 1982 level) 22 percent more cropland will be required. This higher rate of export growth is not expected, but if it occurred, it would stretch land use to a level only moderately above the readily convertible level of 17 percent; well below the 30-percent potential in the high- plus medium-conversion categories.

These projections, 50 years of history, and the fact that a large amount of cropland was diverted from production in 1983 under government supply management programs all suggest that cropland availability will not limit agricultural expansion during the next two or three decades. U.S. agriculture can find additional cropland if it is needed. The larger question is: how might the present land base be reallocated among alternative and more intensive uses? A substantial increase in exports might encourage conversion of more land into agriculture but the major effects would be changes in the land use pattern of existing cropland and increases in land rents. Concerns would then focus less on the quantity of land brought in to meet increasing export needs than on the extent to which rental rates rise, capital gains accrue to landowners, and income is redistributed.

It is not known how much additional land would be offered to agriculture if farmers were willing to pay more for it than they now do. It is reasonable to assume, however, that the supply of land in the aggregate is relatively inelastic. A moderately inelastic supply function for land was assumed in the cross-sectional study. Results were then compared with a highly inelastic supply function for land. An increased rigidity in the availability of land resulted in a more inelastic supply of farm commodities. A more inelastic supply of land means that agriculture is likely to respond to an increase in export demand with higher prices instead of increased output. The major effect was on prices; the total level of and pattern in production was little changed when the elasticity of the land market changed. A change in the demand for farm products was found to have far more impact than a change in the supply of land on land use patterns.

While expanding export markets increase the value of cropland, the effect on pasture and range is different. Exports are mostly of crops and crop products. When the world food situation tightens and crop exports increase, domestic markets also tighten and retail prices increase. This reduces the domestic market from what it otherwise would be for livestock as well as for crops. The narrowing market for livestock reduces the rental value of pasture land, and less is used; possibly 2 or 3 percent less in response to a 90-percent surge in exports, after all adjustments are made.

When export markets are growing relative to the growth in farm production, one response to the resulting tight food situation can be to increase the quantity of cropland. An increase in the supply of cropland would lead to increased output, thus easing the pressures of a tighter world food situation. To the extent that land is a substitute for other farm inputs, such as labor and purchased inputs, the increased use of land can reduce the demand for these and reduce prices paid for them (or limit price increases that would have occurred if additional land had not been developed). However, labor and purchased inputs are, in general, complements with land, so more non-land inputs would likely be used at higher prices paid. An increased supply of cropland reduces land rents just as increased output reduces prices received.

An increase in the supply of pasture land, instead, induces production of more beef, particularly nonfed beef, which domestic consumers substitute for other meats. Some adjustments in food, feed, and export markets for crops are induced, but little change occurs in the aggregate use of, or rental rates for, cropland.

There is a potential to convert additional land into agricultural uses if it is needed. Other problems will likely arise, however, before land availability limits the growth in farm output even if there are moderately decreasing real prices received by farmers. The more inelastic the adjustment in land to an expansion in the market for food products, the higher that food prices are likely to rise. On the other hand, programs to develop agricultural land when the demand for food is not changing are likely to have more of an impact on prices and income distribution than on the quantity and mix of farm output.

Soil Erosion and Export Growth

There seems to be enough land available to meet anticipated export demand, even assuming some loss in cropland due to depletion of soil and ground water resources. However, a major export expansion over the next two or three decades would encourage farmers to bring fragile lands into production. The extent to which erosion becomes a problem as exports expand depends on where cropland expansion occurs. This depends, in turn, on which commodities are exported. Soybean and cotton exports will create more erosion problems than wheat exports will.

The amount of potentially erosive land that might be converted to crop use varies widely among regions. Some of the most severe problems are associated with parts of the Northern Plains, High Plains, Corn Belt, Delta, and Central Plains. However, susceptibility of potential cropland to erosion varies among these regions. Virtually all the potential cropland likely to be used if soybean production expands in the Delta is eroding by more than 5 tons per acre per year. Nationally, less than 5 tons is considered acceptable; but the acceptable rate varies among regions. The Corn Belt has more erosive acres that can be converted to cropland than the Delta, but it also has more nonerosive acres. Therefore the relative potential for erosion is greater in the Delta. In contrast, expansion of wheat production in the Northern Plains presents few erosion problems.

The most damaging recent increases in soil erosion came from expansion of soybeans in the Delta and dryland cotton in Texas as the export markets for these crops grew. Next to Texas, Tennessee and the Delta States have the highest potential for severe erosion. Since 1972, Texas cotton acreage has risen from 40 to nearly 50 percent of U.S. cotton acreage. Although most Texas cotton is irrigated, declining water tables and higher pumping costs are causing shifts to dryland farming. Wind erosion on dryland cotton is rarely less than 25 tons per acre per year. There is no shortage of land in the High Plains to meet expanding cotton export demands, but growth will occur on fragile soils.

About 10 percent of current soybean acreage erodes at critically high rates. If exports rose by 90 percent, soybean acreage likely would increase by 30-50 percent in each of the major soybean-producing areas (*111*). Ogg estimates that roughly half of the new production would likely come from soils eroding at 4 or 5 times the levels considered acceptable (*184*). Production on these fragile soils is generally not sustainable even with heavy investment in conservation practices.

Expanding and changing markets could lead agriculture to a position of unsustainable growth. This pessimistic outcome can be avoided by expanded investment in soil conservation measures, such as terraces, reduced tillage, and stripcropping on the half of the cropland in use which is moderately erosive and is responsive to management practices. Eight percent of the cropland in use is so inherently erosive that it will not sustain continued cropping. Volatility of export markets tends to dampen incentives to adopt conservation practices and to increase the likelihood of erosion problems.

About half of the potential cropland is so erosive that it is probably not treatable at any reasonable cost. If these lands are used they will be depleted, so a sustained rise in exports cannot be based on them. Measures to direct some of the new production to the substantial acreages of potential cropland that are less susceptible to erosion include requirements that farm program participants avoid new cultivation on fragile lands, or targeting price support acreage reductions to fragile areas. Perhaps one-half to two-thirds of the total erosion problem could be addressed through modification of commodity and conservation programs.

It is possible to use presently available land to meet future export demands without pushing natural resources to the limit. But there could be soil erosion and productivity problems for some crops in some regions. Those problems, if disregarded, could limit agricultural capacity in the longer term. Crosson and

Brubaker argue persuasively that public intervention is justified in order to avoid loss of capacity through soil erosion (*46*).

Irrigation

Additional irrigation is not likely to be a source of agricultural growth in coming decades as it was following World War II. However, there could be increases in output from additional supplemental irrigation in humid areas. A likely scenario for U.S. irrigation for coming decades is to use about the same amount of water more effectively to support an increasing quantity of production at higher unit costs.

Nearly 51 million acres were irrigated in the United States during 1978, consuming more than 93 million acre-feet of water (an average of 22 inches of water per irrigated acre for a total of about 6.5 trillion gallons). About 54 percent of the irrigation water is from surface watercourses and the rest is pumped from ground water aquifers. Agriculture accounts for 84 percent of the water used in the United States.

In many parts of the United States, irrigation is necessary for crop production. In the arid parts of the West, there is no choice but to irrigate, and the irrigation water requirements per acre are higher than the national average. Crop production in Nevada is 100 percent irrigated; in Arizona, 99 percent. In seven Western states, more than 60 percent of the crop production is irrigated. Those States are, in order of percentage irrigated: Nevada, Arizona, California, Utah, Wyoming, New Mexico, and Idaho.

Fourteen States, each irrigating over 1 million acres per year, consume nearly 90 percent of the irrigation water. Twelve of these States are in the arid West. They are, in order of acres irrigated: California, Texas, Nebraska, Idaho, Colorado, Kansas, Montana, Oregon, Wyoming, Washington, Arizona, and Utah.

In humid regions where irrigation water requirements are below the national average, there is room for choice and substitution. Irrigation supplements rainfall in order to increase intensity of land use, improve yields, and insure against drought (*8*). Florida and Arkansas are humid States that each use supplemental irrigation on over 1 million acres per year.

Certain crops rely more on irrigation than others. For example, 100 percent of rice production is irrigated. Eight classes of crops are reported in the agricultural census that are more than 50-percent irrigated. They are, in order of percentage irrigated: rice, orchards, potatoes, sugar beets, vegetables, berries, alfalfa seed, and green beans. Exports are an important source of demand for some of these, but only rice is a major export crop.

Corn uses more irrigated land in the United States than any other crop, about 20 percent. Corn, hay, and small grains used for feed together use nearly half the irrigated cropland. Irrigated grains are important in export markets. However, irrigation is more important in the support it gives the large domestic feed-livestock economy. Soybeans, which are important in exports, use only about 3.6 percent of irrigated cropland.

If world food supplies become tight in coming decades, one way to meet additional food needs is through increased irrigation. Irrigation increases yields and, more important, it permits cropping on land that would not otherwise be cropped. The U.S. average yield for irrigated wheat is 92 percent more than for dryland; irrigated corn is 20 percent more. Irrigated soybeans is only 5 percent more, which may explain why so little soybean production is irrigated. Rice production would be virtually eliminated if there were no irrigation.

When the acreage planted to a given crop is increased by irrigation, a regional relocation is usually implied. This location effect explains why a yield-increasing expansion in irrigation sometimes may appear to reduce the U.S. average yield. The added irrigated acreage generally is not in the same region that contains most of the production. Corn illustrates this point. Irrigated corn yields in Iowa are only 2 percent more than dryland yields there. In New Mexico, irrigation raises yields by 119 percent, yet the irrigated yield in New Mexico is 15 percent less than the dryland yield in Iowa. Therefore, as corn production expands on irrigated land in New Mexico, the aggregate U.S. yield is reduced.

When crop exports increase, Horner found that most of the added production is on dryland. A 90-percent increase in exports, assuming constant yields, would require 25 percent more dryland and 7 percent more irrigated land after all adjustments to the change are complete (*108*). The quantity of irrigated rice is highly responsive to variations in exports because all rice is irrigated. For example, additional soybeans and cotton would be irrigated for smaller increases in exports. But only for the high-export scenarios would resource constraints be tight enough to induce extensive irrigation of corn and wheat. A lack of irrigation water is not likely to limit the ability of U.S. agriculture to meet export demands during the next two or three decades, according to this cross-sectional analysis. However, tight world food supplies, and consequently higher prices received by farmers, would increase the prices that farmers are willing to pay to irrigate.

The availability of additional irrigable land is less limiting than water. There is more irrigable land than the 50.8 million acres now in use, but we will be unlikely to increase the quantity of irrigation water much above the 93.1 million acre-feet now used. A doubling of irrigated acreage during the past three decades supported considerable expansion in agricultural production. Prospects for additional growth in this way are limited. Most of the less costly supplies of surface water in arid regions have already been developed, and the real cost of water is likely to rise. The distance that water must be moved from its source to the point of use is increasing as is the cost of energy to move the water. However, the water supply is more manageable in humid areas such as Georgia, Florida, and Arkansas than it the arid West. "As water is becoming an increasingly limiting factor in the dry regions of the West, a significant potential of further development lies in the humid regions of the East" (*9*).

An increase in supply of water offered to farmers at present prices would not induce much of an increase in farm output. Similarly, a decrease in the supply of water would not reduce output much. The demand for water by farmers is estimated to be relatively inelastic, so small changes in the availability of water have more of an effect on the price of water than on the quantity used. Consequently, a shift in either the supply of water or the demand for farm products has greater implications for the redistribution of income among water users and water suppliers than it has on the quantity of water used.

Agricultural use of irrigation water in coming decades will probably be about the same volume as now. New water sources will probably be about offset by reductions in existing supplies. Reductions in the level of use may come from a loss of present supplies, contamination, and competiton with nonfarm uses. Disposal of wastes at industrial impoundments and solid waste disposal sites is the major source of ground water contamination. If prices received by farmers increase relative to energy costs, there will be an incentive to pump more ground water. Too much pumping could threaten longrun prospects for a stable water supply (*107*).

The value of water in nonfarm uses is increasing. Under these economic pressures, the institutions now in place to allocate water among alternative uses might be modified to allow increased municipal and industrial use of some of the water now used by agriculture.

The institutions used to allocate water among alternative uses are proving disruptive during the transition from cheaper to more expensive water according to Frederick and Hanson (*72*). The U.S. Water Resources Council concluded that if present national patterns of water use continued, conflicts would arise for which no simple solutions would be available; attempts to correct a problem in one region may compound other problems in the same or in other regions (*287*).

To the extent that the institutions that allocate water among alternative uses become relatively more like free markets, several things likely would happen. Water prices to agriculture would increase and water would be used more efficiently. The same amount of water might be applied to more acres, but more nonagricultural competition for water would bid some water away from agriculture. The latter likely would be the most important response in some regions. Higher marginal costs of using water and increasing marginal returns for producing scarce food products would lead to a reallocation of water within agriculture as well as between farm and nonfarm uses. High-value crops such as vegetables and fruits would bid water away from crops grown for the feed-livestock economy. However, unless the domestic or foreign demand for high-value crops increases, this would not occur to a great extent because the markets can easily be saturated. Irrigated feed and food grains would replace irrigated forage crops. Dryland crops would replace some irrigated crops. Free market allocations of water between farm and nonfarm uses would result in higher unit water costs for farmers, increased concentration of irrigated agriculture, and a net reduction in the use of irrigation water (*168*).

The output of irrigated crops from present water supplies can be increased in various ways. More efficient application systems are being developed and present systems can be used more effectively. Adoption of "waste management" facilities and practices can increase the effective supply of water sufficiently to

Resolving Water Use Conflicts

During the late 19th century, farmers found that diversion of scarce water from rivers and streams for irrigation created conflict among users. They organized into water districts to build water storage and conveyance facilities. The Federal Reclamation Act was enacted by Congress in 1902 to authorize the Bureau of Reclamation to build irrigation projects in the West. Projects under this program now irrigate about 24 percent of the irrigated acreage in the 17 Western States. Most of this water has been developed and allocated to farmers by government decree; market forces of supply and demand were not considered.

Two systems of legal rights to water have developed in the United States: the riparian doctrine and the appropriative doctrine. Under *riparian rights,* owners of land contiguous to a watercourse have a legal right to divert and beneficially use that water. They do not forfeit the right to water by not using it. This system confines irrigation to land contiguous to watercourses. It applies in some Western and most Eastern States.

Appropriative rights were developed in most Western States to permit water to be used on productive land not contiguous to a watercourse. This system ranks rights by the order of filing the claim to the water. The junior appropriator must reduce use of water first in times of shortage. The appropriative right can be lost if it is not used. The resulting pattern of water rights allocates some water to uses whose value is less than the value of the water.

meet the additional water requirements associated with a 90-percent increase in exports. The incentives to increase the volume of output from the present quantity of water are not high given present price ratios and the institutions affecting water allocation. Higher and more stable world food prices would increase these incentives. Lower and more uncertain real food prices would reduce incentives.

Purchased Farm Inputs

Availability of farm inputs is expected to be sufficient for agricultural growth during the next two or three decades. The total inputs into U.S. agriculture have been relatively constant in recent decades, but the mix of inputs has changed. Farmers are using more purchased inputs and less labor on the same amount of land (table 2). Nearly three-fourths of cash receipts are used for the purchase of farm inputs now compared with around one-third three decades ago (*4*).

Output has been increasing even though total inputs have been relatively constant. The productivity increases of recent decades are highly correlated with the increases in expenditures by farmers for purchased farm inputs (table 2). The availability of inputs and services from the nonfarm sector of the economy during the next two or three decades will be more important in determining the capacity of agriculture relative to market demands for food than the availability of natural resources and labor. Backward linkages, from farmers through farm input markets to the nonfarm sector, are primarily for machinery, materials, chemicals, energy, and various services such as transportation, real estate, and financial services. These linkages are a little stronger for crops than for livestock and therefore are responsive to changes in the export markets for crops. A relatively tighter world food situation tends to improve income and employment in the nonfarm sector that supplies purchased farm inputs.

The nonfarm sector now supplies most of the farm inputs. Growth in agricultural production will depend to a major extent on the offers to farmers of materials, machinery, information, and various kinds of services, including financial services. Farmers do more bargaining in their factor markets than they do in their product markets. They negotiate land prices, contract rents, make bids on machinery, and shop around for the best deal on chemicals and seeds. Often, local input markets involve only a few buyers and a few sellers, so the markets for many farm inputs tend to exhibit imperfect competition, oligopoly, or sometimes monopoly. Farmers can exert some influence on the prices they pay for inputs even when they are price takers in their product markets.

Table 2—Index of farm inputs and productivity (1977 = 100)

Year	All	Nonpurchased	Purchased	Productivity*
1940	97	176	50	52
1950	102	166	61	60
1960	98	131	74	77
1970	97	107	88	87
1980	103	99	106	100

*Ratio of index of farm output to index of all inputs times 100.
Source: Andrilenas and Torgerson (*4*).

Prices that sellers of farm inputs are willing to accept are often affected by opportunities to sell the same or related goods and services to the nonfarm sector. Manufacturers, for example, set prices of farm machinery with recognition of opportunities for sales to construction firms of other equipment they manufacture. Prices in the farm input markets, therefore, are influenced not only by the demand for farm products, but also by the prices of nonfarm producer goods and services. The nonfarm sector is expected to have the capacity to supply farmers with the quantities of inputs needed to meet growing domestic and foreign demands for food; the prices famers pay for purchased farm inputs will be determined in part by what happens to the level of nonfarm producer prices.

Although export expansion increases the demand for machinery, meeting the expected increases with little change in real prices is not beyond the ability of resource suppliers. Gunjal and Heady estimated that a rise in the annual increase in exports to 5 percent per year from 3.75 percent per year would result in only a 0.5-percent increase in investment in 1990 for tractors and other machinery, and approximately a 1.5-percent increase in investment in harvesting machinery (*92*).

If the world food situation were to become tighter than anticipated, one strategy for expanding output would be to increase the supply of purchased farm inputs. It is therefore useful to analyze the effects of such an increase. The distributional effects of an increased supply of inputs tend to counter the effects of a food scarcity. Lower prices paid for purchased inputs would increase farm production, mostly for crops at first. Prices received would decline, and consequent reductions in feed costs would induce further increases in livestock production. The increased flow of farm commodities at lower prices would result in increased domestic consumption, an increased volume of processing and marketing, and increased exports. With purchased inputs relatively less expensive than land and labor, there would be more intensive land use and an accelerated release of labor to nonfarm jobs. This, in turn, would weaken land values and wage rates. Prices received by farmers would decrease by more than the increase in output so cash receipts would drop; reduced costs would be more than offset by the drop in gross income and net income would fall. Consumers, food handlers and processors, and importers would benefit (through increased quantities at lower prices) from the increased supply of purchased farm inputs.

Energy is critical to agricultural growth. Until the early seventies, energy was plentiful and cheap. Since the energy crunch of 1973, this is no longer true. The real price of oil could rise during 1985-90 (*135, 167*). If farmers pay higher real prices for petroleum, natural gas, and electricity, they can keep energy expenditures in check by using energy conservation practices and adopting alternative energy sources: solar heating and cooling, photovoltaics, wind energy, and liquid and gaseous fuels from crop and livestock wastes. New tractors, combines, and farm vehicles will be more energy efficient than the equipment they replace. The horsepower of tractors is increasing so that more work can be done with less labor. Placing fertilizer (for which natural gas is a prime feedstock) precisely where it will be used conserves energy relative to broadcast techniques. Other crop and fertilizer management systems also allow crops to use fertilizer more efficiently, by mixing fertilizer with sprinkler water, for example.

Conservation tillage involves fewer preplant operations, disturbs the soil less, and leaves more crop residue than conventional tillage practices. No-till involves no soil disturbance except for planting. Reduced-till includes a variety of alternative systems that leave a measurable amount of crop residue and reduce soil disturbance. Conservation tillage rose from 2.3 percent of the harvested cropland in 1965 to 10.8 percent by 1975 and 25 percent by 1982. The use of conservation tillage likely will double over the next decade. While conservation tillage offers great promise in conserving soil, it will not become widespread until farmers become more familiar with the techniques, until farmers' fears of lower yields are overcome, until new herbicides are developed to insure adequate weed control, and until research solves problems associated with larger quantities of residue (*56*). Conservation tillage reduces the demand for energy and increases demand for manufactured inputs; it is not likely to have a significant longrun effect on the yield of most crops.

The U.S. food system, from production to consumption, uses approximately 13 percent of the Nation's energy. The real price of world oil likely will increase over the next two or three decades. As petroleum prices increase, two adjustments can be expected. First, users of oil will shift to other sources, such as electricity (increasingly from coal) and natural gas. Eventually, liquid and gaseous synthetic fuels from coal and oil shale may become important. But given the economic risks of heavy investment in synthetic fuel facilities, these fuels might not be produced without some form of government guarantee. Second, over the longer run, energy users will continue to invest in energy-conserving devices and practices, thereby substituting relatively less expensive capital and labor for the more expensive fuels. It could take as long as 8 years for adjustments to a fuel price shock, such as experienced in 1973, to be completed by the economic system; it would take even longer for synthetic fuels to adjust (*167*).

Higher world oil prices generate interest in alternative sources of fuel. Gasohol is of particular interest to agriculture both as a potential market for grain, especially corn, and as a competing use for feedstuffs. In 1980, Congress passed the U.S. Energy Security Act appropriating funds and providing tax incentives with an objective of producing 10 billion gallons per year of gasohol by 1990, or 10 percent of total U.S. gasoline consumption. When corn is used for gasohol production, two major products are produced: ethanol and distillers' dried grain (DDG). DDG, with a protein content of 22 percent, is a substitute for soybean oil meal as a supplement in livestock feed. Thus, as ethanol production increases, soybean acreage is expected to decrease. Some of these soybean acres will be planted to corn.

LeBlanc and Prato estimated that if more corn is produced for ethanol, soybean production would drop (*136*). Prices received for both corn and soybeans would increase, as would net farm income. Side effects include higher food prices to consumers, higher feed costs to the livestock sector, and reduced grain and soybean exports. Despite government incentives for gasohol production (a direct Federal subsidy of 5 cents per gallon, Federal construction subsidies and tax advantages, and exemption from some State gasoline taxes), gasohol is not competitive in the marketplace and is unlikely to play a major role in total energy production.

Another alternative fuel source is oil shale. Large deposits of oil-bearing shale are in western Colorado, Wyoming, and eastern Utah. Development of the oil shale industry could benefit the Nation's economy if the associated economic risks are contained (*180*). Financial and economic feasibility of oil shale extraction do not appear possible before about 1995 (*135*). However, political disruption in the Middle East could cause world oil prices to reach a breakeven level for oil shale at almost any time. The same is true for synthetic fuels from coal.

The impact of limited energy supplies and rising energy costs on U.S. agriculture could be pervasive. Most heavily hit likely would be irrigated regions of the West that are dependent on ground water pumping, areas heavily dependent on sprinkler irrigation, and areas of the Corn Belt where grain drying is extensive. Fertilizer use may stabilize or decline. Irrigated agriculture will probably adjust to higher energy and water costs in the short run by substituting additional capital and labor for energy and, in the long run, by switching to crops with lower energy and water requirements. Grain producers may grow shorter-season varieties and turn to alternative energy sources such as solar drying.

Higher real energy prices will probably limit growth in newly irrigated acreage, especially from ground water sources. As real energy prices increase, the economic supply of ground water for irrigation will be reduced. An increase in exports, however, with concomitant increases in real commodity prices, would allow continued pumping of ground water. Another depression of real prices (similar to the 1982-83 drop) would idle some irrigated land in arid regions while land in moderate rainfall areas, such as the Great Plains, would revert to dryland farming. Energy supply disruptions can cause temporary changes in food production but are not expected to limit U.S. agriculture's ability to meet the domestic and foreign demands likely to be placed on it during the next two or three decades (*135, 167*).

Farmers are responsive to changes in the prices of purchased farm inputs relative to one another and relative to the level of prices received. The ratio of prices received to prices paid has generally decreased throughout this century and is expected to continue to decrease in coming decades. During the seventies, prices paid for agricultural chemicals declined relative to prices received for farm products. And relative prices paid for fertilizer increased since the early seventies to about the same level as they were during the midsixties. Higher prices and reduced requirements limited expenditures for buildings and machinery.

Purchased farm inputs are expected to become increasingly important as a basis for agricultural growth. The nonfarm sector appears to have the potential to satisfy increasing demands for purchased farm inputs. Issues will arise over prospective increases in the real level of prices paid by farmers, particularly for energy intensive inputs, and over the competitiveness of farm inputs markets (including those for natural resources and labor). Farmers' purchases of nonfarm inputs are intimately related to changes in agricultural technology. As farmers continue to adopt new ways of doing things, issues will surface associated with the relationship of purchased inputs to resource productivity, income distribution, and the effect of various production practices on food purity and environmental quality.

Increasing productivity and expanding markets, particularly export markets, continue to expand farmers' demands for purchased inputs. The quantity of purchased inputs offered to farmers will continue to expand, but the relative prices paid by farmers will continue to increase. The availability of purchased farm inputs is not expected to become a limit to growth during the next two or three decades.

Farm Labor

Growth in export markets may make labor a more important determinant of agricultural supply response than in the past few decades, but labor is not expected to limit the ability of U.S. agriculture to meet domestic and foreign market demands during the next two or three decades.

The population on U.S. farms was 7.2 million in 1980, about 3.3 percent of the total resident population. Farm employment was 3.7 million, of which 2.4 million were family and 1.3 million hired. The longrun trend of farm population and employment has been emphatically downward (table 3). This is consistent with an increasingly productive agricultural industry, a transfer of many processing, transporting, and handling jobs to the nonfarm agricultural marketing sector, increased purchases of nonfarm inputs, and changes in relative factor prices.

Farm employment frequently has not been included as a potentially limiting variable in analyses of U.S. agricultural production. A reason for this is that farm labor was in surplus; the problem was to find nonfarm uses for the labor that was released from agriculture. This situation is changing. A net of 23.3 million persons left the farm since 1940; only 7.2 million are left. Beale noted that "this was one of the largest voluntary migrations in human history.. (*12*, p. 80). The pace of outmigration from agriculture halved the farm population every two decades. Even if this pace were to continue, the importance of outmigration of farm people is over as a major social force in the U.S. economy. Furthermore, the pace slowed in recent years and

Table 3—Farm population and employment, 1940-80

Year	U.S. population[1]	Farm population[2]		Farm employment: Farm labor survey[3]			Farm employment: Current population survey[4]
				Total	Family	Hired	
	Million	*Million*	*Percent of U.S.*	*Million*	*Million*	*Million*	*Million*
1940	132.6	30.5	23.2	11.0	8.3	2.7	9.5
1950	152.3	23.0	15.3	9.9	7.6	2.3	7.2
1960	187.7	15.6	8.7	7.1	5.2	1.9	5.5
1970	204.9	9.7	4.8	4.5	3.3	1.2	3.5
1980	221.7	7.2	3.3	3.7	2.4	1.3	3.4

[1]Total resident population, U.S. Census.
[2]Previous definition of a farm. Using the definition adopted in 1978, there were 6.1 million people living on farms, 2.6 percent of the total residential population.
[3]Statistical Reporting Service, Farm Labor Survey. Previous definition of a farm.
[4]Bureau of Labor Statistics, Current Population Survey. Persons 16 years and older.

agriculture showed some signs of labor retention during the rapid export growth of the seventies.

Use of hired labor stayed about the same during the seventies, according to the farm labor survey (table 3), as acreage for export doubled, the pace of large-scale mechanization slowed, and family labor used on farms continued to fall. The current population survey, which samples a different group of people and uses a different definition of a farm, also indicates retention during the seventies. If the world food situation tightens and exports continue to rise toward two-thirds of harvested acreage, the total labor requirements for some export commodities will increase despite continued technological, labor-saving improvements.

The impact of exports on farm employment varies among crops and regions. Farm labor policies in coming decades may focus less on finding nonfarm jobs for those displaced from agriculture and deal more with adjustments such as the increasing proportion of hired relative to family labor.

While a scarcity of farm labor is not imminent, a drop in the supply of labor would limit farm production, according to the cross-sectional analysis. If that happened, livestock production would be limited more than grain and oilseeds. Prices received by farmers would rise to more than offset the output reduction, so gross income would increase. Feed costs would rise and thus further limit livestock output. Demand for other farm inputs would decrease, prices paid would fall, and farm income would increase. Owners of resources that are complementary with farm labor would sell less at lower prices.

Some regional shifts would result even if the supply of labor tightened uniformly across the country. The adjustments to reduced availability of labor would be most responsive for cotton in the Pacific region and for hogs in the Northern Plains, according to the cross-sectional analysis. It would be least responsive in the Corn Belt. Total cotton production would be little changed, but more would be grown in the Southeast and Delta regions, which have been reducing cotton acreage in recent years, and less cotton would be grown in the Pacific States. Livestock production would be reduced most sharply in the Lake States, Appalachian, and Delta regions.

Technology

Agricultural production depends not only on the quantity of resources available but also on the productivity of resources used. A technological advance is a change in the way of doing things that increases the flow of outputs relative to inputs. Despite earlier technological advances, like the moldboard plow, irrigation, refrigerated railroad cars, tractors, hybrid corn, and chemical fertilizers, growth in food production also depended on increases in the total resources used. This changed during the thirties. Total resource use is about the same now as it was then (table 2) but output has grown through resource substitutions and new ways of doing things. Expanding demand and reduced availability of farm labor during World War II stimulated adoption of the cotton picker and set off a decline in farm labor that did not level off until the seventies. The number of tractors peaked in 1965, when the decline in farm numbers overtook the adoption of mechanized technology.

The productivity index (table 2) is the ratio of the index of farm output to the index of farm input. Though there is a great deal of uncertainty about what is shown in measures of aggregate productivity, as pointed out by Langham and Ahmad, growth rates over time do provide an indicator of progress (*134*). The productivity index has been rising for the past three decades at an average annual rate of 1.9 percent per year. This rise is usually interpreted as a reflection of new technologies, although it was affected by structural and institutional changes and by farmers' adjustments within known technologies to changes in relative prices.

Following World War II, growth in food production exceeded growth in markets. The midsixties were marked by commodity surpluses and a relatively low rate of capacity utilization in agriculture. Harvested acreage was historically low through the sixties, attaining its minimum in 1962. The acreage reduction programs of the sixties accelerated the use of fertilizer as the program payments and commodity support prices increased receipts relative to the price of fertilizer.

During the seventies, the growth in productivity appeared to slow (to only 0.6 percent per year) even as output was rapidly rising for export. The slowdown raised questions, reviewed by Lu, whether technological advance in agriculture was approaching a limit at the same time that cropland harvested was approaching its historical high (*148*). However, the slowdown may have been more apparent than real. More corn was grown outside the Corn Belt, closer to shipping points, where corn yields are lower. This reduced the weighted-average corn yield. Second, more crops were produced relative to livestock. Since crop productivity indexes include more inputs per unit of output, Teigen showed that the weighted average of both commodities reduced the aggregate measure (*238*). These two points are expanded below; they suggest that much of what appeared to be a change in productivity was attributable to shifts among commodities, resources, and regions in response to changing market conditions and to weather.

Before the midsixties, livestock production grew more rapidly than crop production. Crop yields increased and production grew more rapidly than the markets could absorb at current prices; acreage was reduced. Since then, growth in crop production has doubled its earlier rate, spurred by growth in export of grains and oilseeds. At the same time, the growth in livestock production was reduced to a little less than the growth in U.S. population.

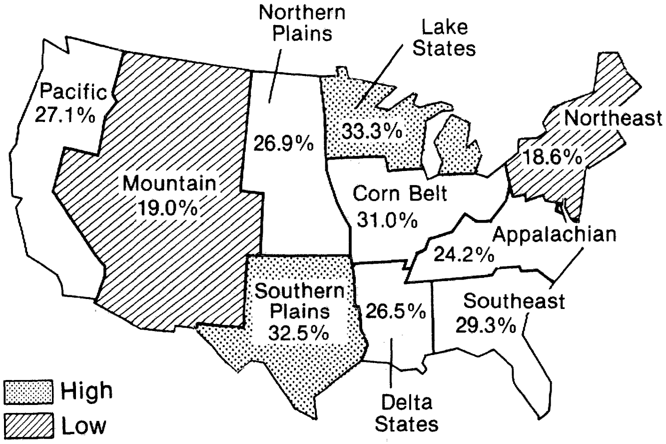
On balance, the increased growth of crop production offset the slower growth of livestock production and total farm output expanded steadily over the past four decades. There was little change in aggregate resource use and the advance in output is attributed to an increase in resource productivity. However, crop production requires more purchased inputs, including fertilizers and chemicals, than livestock production, so that the growth in productivity, measured as the ratio of aggregate output to aggregate input, appeared to slow down as the mix of crop and livestock products changed (*238*).

Regional variations in crop production explain some of the apparent slowdown in productivity (fig. 7). In the Corn Belt, Plains, Delta, and Mountain regions, total crop production increased and yields followed a stable, rising trend. Production and yields changed little in the Northeast. The Lake States, Pacific, Appalachian, and Southeast regions had significant increases in production, but this was accomplished through increasing inputs, particularly cropland, with no advance in yields. Yields tend to fall as acreage increases and also as the price of fertilizer rises relative to commodity price. When the effects of land, fertilizer, chemicals, and weather are accounted for, significant annual trends in yields were strongest for the Corn Belt, Plains, Mountain, and Pacific regions.

Commodity and regional adjustments permitted the aggregate indicator of productivity growth to slow during the seventies even in the absence of a slowdown in technological advance. The productivity index resumed its growth again during the eighties. Reports of new technology being developed for agriculture suggest that the productivity of agricultural resources can be expected to continue to increase in coming decades.

Figure 7

Regional Growth in Farm Production, 1969-81
(Index of Farm Output per Unit of Input)



Prospects for further technical change include genetic engineering and a new generation of more specialized and computerized machinery (*238*). Other prospects include: remote machinery monitors, controls and robotics; reduced-tillage and no-till practices; crop varieties that are more pest resistant, higher yielding, capable of being grown in new geographic locations, and that have shorter growing seasons; placement of fertilizer and pesticide in the soil close to the seed; crop growth hormone changes; drought resistant and salt-tolerant crops; nitrogen fixation by grass crops; biological pest controls and vaccines; control of animal reproduction; more efficient animal feed conversion; livestock growth hormone changes; and alternatives to traditional livestock and crop products to satisfy human nutrition requirements. Improvements in information flows and decisionmaking by farmers will increase efficiency. Adoption of microcomputers by farmers is increasing the quantity of food that farmers supply at a given price (*157*).

Emerging biotechnologies and genetic engineering have made dramatic progress during the past two decades. Some results have already been adopted by farmers. Photosynthetic enhancement, plant growth regulators, cell and tissue culture operations, gene transfer technology, and biological nitrogen fixation in corn will affect farm productivity measurably by the end of the eighties.

The rate of photosynthesis affects plant yields, according to indirect laboratory evidence. So far however, no increases have been recorded in commercial corn yields due to increased photosynthesis rates. Plant breeding based on selection for the carbon dioxide exchange rate is expected to enhance the photosynthesis rate. Air pollution, by changing the ozone level, slows the rate of photosynthesis and reduces corn and soybean yields. Research is needed to evaluate this problem and to determine the need to reduce concentrations of ozone or to increase ozone resistance in affected crops.

Plant growth regulators (PGR) are organic compounds, other than nutrients, that modify physiological processes in plants. PGR's increase yields by increasing the grain's proportion of the plant's total dry matter.

Genetic modification of plant cells has been made possible by recent advances in molecular biology, cell and tissue culture, and gene transfer. This will augment the genetic modifications that have taken place for thousands of years by natural and human-guided selection. Gene transfer at the cellular level involves two approaches: protoplast fusion (combining the genetic material from two cells into one cell) and DNA transfer via bacterial plasmids or viruses that carry DNA into a host plant. The development of cell and tissue culture has facilitated the regeneration of plants from undifferentiated cells, the transfer of genetic material from one species to another, and mass propagation. Although the ability to culture plant cells has existed since the thirties, the regeneration of whole plants from the cultured cells for corn was first reported in 1975. This innovation will reduce the time required to develop new varieties.

Biological nitrogen fixation involves microbial activity in which atmospheric nitrogen, which is in the air within the soil, is directly usable by the plant. The mechanisms likely to bring about nitrogen fixation in corn are: forming a symbiotic relationship between free-living microbes and the corn plant, or inducing the corn to form nitrogen-fixing nodules on its roots. This could reduce nitrogen application by at least one-fourth of current application rates.

Research is underway on methods to regulate animal appetite and feed intake, enhance cellular growth processes, and improve the synthesis of feeds into protein. It is estimated that a bovine growth hormone can increase milk yields per cow by 20 per cent. Improved disease resistance and immunities are being discovered. Germ plasm changes will result in improved breeds and strains. More efficient reproductive methods will use advanced embryo technology and sexed semen.

The aggregate rate of technical advance glosses over myriad details about individual advances in science and invention, development and marketing of new products, and education on how to incorporate the advances into practical farm management practices. During the past century, advances in agricultural technology had public support through the USDA-Land Grant University system for research, extension, and education (*23; 174,* Vol. 1, p. 1). Recent developments in high-tech methods of farming and recent changes in patent and copyright laws portend a shift in emphasis to more private and less public agricultural research (*57*). Policy issues will arise as to the extent technological developments continue to be in the public interest as they meet private goals.

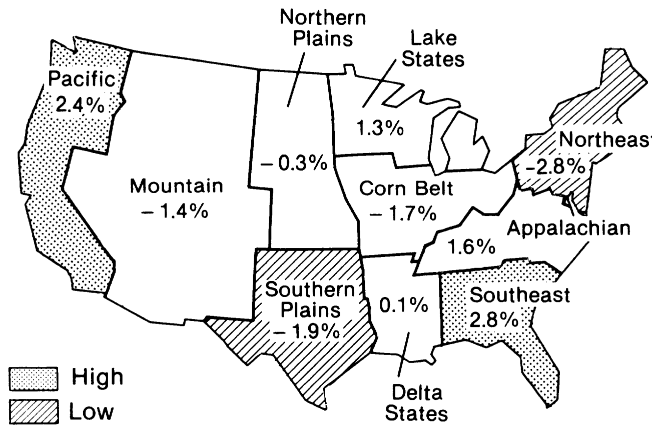
Adoption of new technology can increase farm output and reduce the demand for traditional farm inputs, according to the cross-sectional study. With an inelastic demand for food, prices received by farmers would decrease and gross income would be lower. Fewer inputs would be required so prices paid by farmers would decrease. Net farm income would drop, as would incomes to suppliers of land, water, labor, and purchased inputs. The increased availability of food products at lower prices would benefit consumers, trading partners, and the domestic marketing sector. A major benefit to agriculture would be to keep it competitive in world markets.

Technology hits unevenly within agriculture. For example, if farmers increased corn yields by adopting a series of technological advances, production of corn would increase and the price received would decrease, according to the cross-sectional study. More corn would be used for food, feed, industry, exports, and carryovers. With corn relatively cheaper, production of barley, oats, sorghum, and possibly wheat, would fall. Cheaper feed grain would induce more livestock products, particularly beef and pork. As more meat products moved into domestic markets at lower prices, the demand for inputs to livestock enterprises—pasture land, labor, high-protein feed, and certain purchased inputs—would increase. More soybean meal would meet this increased demand for protein feeds, but less would be grown of most other crops. Soybean oil, a joint product with soybean meal, would increase in supply, so the price of soybeans would weaken despite the increased demand for soybean meal. Demands for inputs for crop production would decrease as demand for inputs for livestock production increase. Aggregate net farm income would fall as would total payments to input suppliers. Regional variations in net farm income (gross income less variable costs) resulting from the cross-sectional analysis of an increase in corn yields are shown in figure 8 (*38, 111*). Benefits of increased food supplies at lower prices accrue, through the forward linkages from the farm gate through the marketing sector, to domestic consumers and trading partners.

If growth in productivity continues for the next 30 years at the 1.9-percent-per-year pace of the past 30, total farm output will increase by 70 percent above the present level. With domestic markets likely to increase by under 1 percent per year, a 1.9-percent-per-year increase in productivity would support a 3-percent-per-year increase in exports. Current expectations are for U.S. exports to increase at close to 3 percent per year in coming decades. In addition, adoption of technology is likely to accelerate. Consequently, technological advance is not likely to be a limiting factor in the ability of U.S. agriculture to meet the domestic and foreign demands likely to be placed on it during the next two or three decades.

Figure 8

Regional Change in Net Farm Income in Response to 10-Percent Increase in Corn Yields



Regional Location of Enterprises

There is regional specialization in crop and livestock production. Regional patterns change over time; for example, cotton shifted from the Southeast to the Southwest following World War II. Double cropping, humid area irrigation, and crop varieties with shorter growing seasons induce regional shifts. Changes in export markets have important regional implications. Expanding corn exports during the seventies led to increased production away from the efficient Corn Belt to lower yielding land closer to Gulf shipping ports; and expansion of soybean exports led to increased production in the Delta where potential cropland is highly subject to erosion. Population shifts from the frostbelt to the sunbelt are intensifying the urban and industrial competition for land, water, and other resources used by farmers (*167*).

Further shifts induced by changing exports likely will raise issues concerning accompanying changes in the regional distribution of farm income. It will also raise issues concerning the regional responsibilities for research on commodities that are undergoing a shift in location; for example, research at the Iowa Agricultural Experiment Station of benefit to Georgia corn growers, or at the Georgia Agricultural Experiment Station of benefit to Texas cotton growers.

Institutional Arrangements Affecting Farmers

A number of institutions affect the supply response of U.S. agriculture to changing world food markets. Many of these can be discussed in conjunction with the issues they directly affect. For example, a discussion of general agreements on tariffs and trade is an integral part of the export issue, and a discussion of institutions affecting water rights is an integral part of the resource availabilities issue.

We usually think of changes in productivity as indicators of technical change, but when the indicators are based on aggregate, national statistics, they can be affected by shifts within the aggregates, such as a change in the size distribution of farms, ownership patterns, legal form of organization, or commodity specialization. Crop yields tend to be higher on farms with more acres, higher sales, specialized, incorporated, and with operators who are part owners or tenants, or who are in their midthirties to midforties. Hence, the supply of farm products is related to the structure of agriculture.

There are some institutional arrangements that, while not directly in the domain of agricultural policy, have important implications for the size of domestic and export markets for farm products, and for the supply response of farmers to changes in these markets. These institutions include national monetary controls, tax laws, and factors affecting the level of government deficits. For example, higher interest rates affect both the demand for and supply of farm products. Higher interest rates increase exchange rates and thereby increase the real price of U.S. food products in world markets. And higher interest rates discourage investment in farmland and capital and thereby decrease the supply of food. The effect of nonfarm economic and political institutions on the efficiency and equity of agricultural production to meet domestic and foreign demands for food will be an issue in coming decades (*20, 120, 210, 245*).

Conclusions

Growth in both the domestic and export markets for U.S. agriculture is needed during coming decades to absorb the growing production potential without depressing prices. Domestic markets are growing relatively slowly. Programs have supported the development of new uses for farm products and have distributed food at home and abroad to those who lack the purchasing power to buy enough to eat at current market prices. But, given the prospect for growth in production, either some major new domestic market will have to be developed (such as industrial uses of farm products, including gasohol) or export markets must be relied upon as a source of growth.

Farm policies will probably have to cope, over the next two or three decades, with a continued decline in the ratio of prices received by farmers to prices paid, and with continued price variability of foreign origin. Farmers have the flexibility and resilience to make most of the adjustments needed to cope with these changes. However, they may, at times, need protective intervention by government. If the United States again supports domestic prices above world prices to protect farm incomes, it may again price U.S. farmers out of world markets and slow the growth of export sales. However, if it provides no protection and allows protective policies of other governments to shift instabilities from themselves to the rest of the world, U.S. farmers and consumers will be hurt by the resulting price volatility. The basis for domestic farm income support and price stabilization policies is changing, primarily because of increased reliance of U.S. farmers on export markets that are volatile and that are growing more slowly than the domestic potential to fill them.

Growth in exports slightly below 3 percent per year is anticipated; that is about enough, given the trend in domestic demand, to absorb anticipated growth in agricultural capacity, even if the moderate downtrend continues in real prices received by farmers. The longrun decline in real prices received by farmers is expected to continue for three reasons. First, the trend has been in that direction for more than a century, and nothing in the present situation points to a new and compelling reason for concluding that a change has taken place. Second, U.S. agricultural capacity can grow faster than the markets are growing. Farmers show a propensity to produce more than will clear the market at current prices. This force for decreasing real prices need not be strong, but it reinforces the other two forces. Third, world agricultural capacity is growing faster than world markets are growing. If U.S. farmers are to expand exports, then real prices received for exported commodities will have to fall gradually to remain competitive.

Price volatility returned during the seventies to the level of the forties and earlier. The atypical price stability of the fifties and sixties was attributable to U.S. price support policies that maintained domestic prices above world levels and permitted accumulation of burdensome carryover stocks. Except for the war years, volatility earlier in this century was attributed to domestic sources including weather and instabilities in urban markets. The major source of volatility now appears to have shifted abroad, particularly to policies of major governments. These include decisions to import to stabilize domestic supplies instead of "tightening the belt" regardless of the destabilizing impact on others, and embargoes for political or diplomatic purposes. Prices are not expected to return to the unusual stability of the fifties and sixties.

Growth in the physical capacity of the U.S. farm sector seems to be adequate to meet expected food demands. U.S. agriculture can produce enough to meet domestic and export demands for food, even at moderately decreasing real prices, as long as efforts continue to conserve and develop natural resources, discover new technologies, promote efficient regional relocations of enterprises, and maintain an increasing supply of purchased farm inputs. Temporary strains are anticipated again, perhaps even as severe as those in the seventies. Lester R. Brown said toward the close of that stressful period that "the problems are manageable but managing them satisfactorily will require an exceptional exercise of political will and human ingenuity" (*31*). Later, Batie and Healy subscribed to a similar view of the future, which they called "guarded optimism" (*11*). Since those comments were made, pressures on food supplies have eased. No doubt, supplies will periodically tighten and ease again. But for the long run, the physical capacity problems seem to be manageable. Strains placed on U.S. agricultural capacity need not lead to prolonged food shortages.

While physical limits on capacity are not anticipated, there may be institutional ones. Another doubling of exports within the short period of one decade, as happened during the seventies, would again strain the agricultural economy by inducing changes in relative prices, income distribution, farm size, ownership patterns, and other structural attributes. Other factors, which are not considered agricultural, can limit agriculture's supply response: high interest rates, credit rationing, and a substantial strengthening of the dollar against the currencies of importing countries. Managing these institutional limits on food capacity is likely to require, from time to time, an "exercise of political will and human ingenuity."

Strong growth in traditional exports (mostly corn, wheat, and soybeans) induces changes in relative prices and incomes that favor crop growers, input suppliers, and trading partners but not necessarily livestock growers, postharvest handlers, or consumers. This distributional trend will raise issues for agricultural policy to deal with in coming decades.

Given the prospects for runs of a few years of relative shortages followed by a few years of relative plenty, shortrun income shifts of large proportions may occur from time to time. These shifts will favor first one group, then another. Shortrun but large changes, due, for example to a few consecutive years of inflationary rises in consumer food prices or, alternatively, to a few consecutive years of reduced exports, depressed farm income, and falling land values, could put strong pressure on agricultural policy in coming decades. Policies for the late eighties and beyond need to be flexible enough to deal with these issues as they arise, or to avert them through stabilization; polices to share the risk while at the same time maintaining agriculture's flexibility and resilience in adjusting to change. How farm programs are financed and operated when world food markets are tight or volatile compared with when they are plentiful or stable affects the distribution of food and income among domestic consumers, the marketing sector, farmers, input suppliers, and U.S. trading partners. The equity of such redistributions of income during temporary times of stress could prove to be of more concern for policymakers than the longrun limits to U.S. agricultural capacity.

Nearly half the annual value of farm exports is from three crops—wheat, corn, and soybeans. These are high-tech products of a modern agriculture. At the same time, they are bulk crops with minimal or no postharvest processing. Export of these three crops adds to the income of farmers who grow them, adds to the cost (through higher feed prices) of farmers who feed livestock, and has little effect on the income of other farmers (who grow fruits or vegetables, for example). Furthermore, export of these crops adds little to employment and income in the food-marketing sector. The increase in the U.S. share of world trade in recent years was heavily concentrated in exports of bulk crops, even though world trade in high-value, processed food products (both crops and livestock) was expanding rapidly. The U.S. share of high-value exports diminished.

At issue in the years ahead could well be strategies to maintain a reliable flow of U.S. farm products into world markets, to diversify the types of commodities exported, and to consider the efficacy of exporting higher value food products (both crop and livestock products) as a means of creating nonfarm income and employment in the food and fiber industries. Growth in farm export markets is an important determinant of whether U.S. agriculture will continue to be growing and prosperous, or whether it will increasingly rely on public transfers to maintain income levels in farming, or whether it will undergo a further major adjustment resulting in a much smaller yet prosperous agriculture that produces a reliable supply of food and other farm products mostly for domestic markets.

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Other Reports

U.S. Hog Industry, by Roy N. Van Arsdall and Kenneth E. Nelson. AER-511. June 1984. 116 pp. $4.50. Order SN: 001-000-04408-7 from GPO.

"... an excellent report ... presenting a statistical overview of the industry not available in this concise, readable form in any other publication. I believe my colleagues ... will share my enthusiasm." R. A. Easter, U. of Illinois, Urbana-Champaign

The hog industry has moved rapidly in the last 30 years from barnyard sideline to mechanized million-dollar operation. This report describes the most prevalent practices used today. Includes confinement production facilities, breeding, feeding regimens, waste management, and more. Charts, photos, and 54 detailed appendix tables.

The U.S. Poultry Industry: Changing Economics and Structure, by Floyd A. Lasley. AER-502. July 1983. 32 pp. $3.25. Order SN: 001-000-04342-1 from GPO.

An excellent overview of changes in the U.S. poultry industry over the last 25 years. Examines why per capita consumption of poultry meat in 1981 nearly doubled since 1960, but retail prices rose only 74 percent for broilers, 67 percent for turkeys, and 59 percent for eggs. Vertical integration and technological advances are largely responsible for improved production and efficiency in the industry, enabling producers to hold down costs.

The U.S. Turkey Industry, by Floyd A. Lasley, William L. Henson, and Harold B. Jones. AER-525. March 1985. 72 pp. $3.00. Order SN: 001-019-00385-5 from GPO.

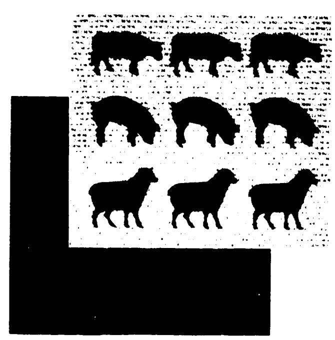
Discusses trends in the thriving turkey industry, an industry which skyrocketed from a modest enterprise with a gross farm value of $270 million in 1950 to a complex agribusiness with a gross farm value of $1.25 billion in 1982. Turkey is now consumed year round, currently about 10.8 pounds per capita annually. The further processed product such as turkey rolls, pot pies, and frozen dinners is the fastest growing sector of the industry.

The U.S. Beef Cow-Calf Industry, by Henry C. Gilliam Jr. AER-515. September 1984. 72 pp. $2.75. Order SN: 001-019-00352-9 from GPO.

This comprehensive look at the U.S. beef cow-calf production industry finds that the number of beef cows fell by about one-fifth between 1975 and 1980 in response to sharp reductions in feeder cattle prices and increases in production costs during the midseventies. Photos and charts illustrate the text.

Characteristics of Farmer Cattle Feeding, by Roy N. Van Arsdall and Kenneth E. Nelson. AER-503. August 1983. 48 pp. $3.75. Order SN: 001-000-04361-7 from GPO.

Now in its second printing, this report examines how the continuing trend toward commercial cattle feeding has reduced the number of farmer cattle feedlots to 113,000 as of 1980, down from 219,000 and 61 percent of the market in 1964. Explains why the number of farmer cattle feeders is expected to decline during the eighties.



Livestock and Meat Statistics, 1983. SB-715. December 1984. 184 pp. $4.50. Order SN: 001-019-00369-3 from GPO.

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